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Investigating the water footprint of Tetra Pak Carton Economy's beverage portfolio

Cong Li
Stephen Ugochukwu Nwokoli

Supervisors
Erik Nordström Matthiessen — Tetra Pak
Rolf Larsson — Lund University

Division of Water Resources Engineering
Department of Building and Environmental Technology
Lund University

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ABSTRACT

Freshwater of good quality is important, even necessary, for human society as well as natural ecosystems to function. However, the uneven distribution of freshwater globally together with other problems such as over-population and pollution all contribute to water stress and water scarcity in many countries. These issues are getting worse and worse. A growing number of companies and organizations have started to recognize the importance of water to their business and have started programs to improve the sustainability of freshwater in their processes.

Virtual Water (VW) is a method used to measure the impact of water trade between countries and businesses. Life Cycle Analysis (LCA) is one of the ways to assess the impact of product on the environment. The concept of a "water footprint" has been developed and defined for countries, businesses and products. More than just being a total figure for the volume of water used in a process, it specifies the type of water used (blue, green or grey water) as well as when and in which process the water is used.

The "Tetra Pak value chain" is a term that describes the water usage from the raw material to the finished product, involving suppliers, Tetra Pak themselves as well as the customers. Both quantitative and qualitative research methods were used in this project to understand the water footprint in the Tetra Pak value chain.

This report develops the explanation of "water footprint" and discusses the difference between gross green water, net green water and embedded water. The concepts of "water use" as opposed to "water consumption" are developed to assist the understanding of the main water processes at Tetra Pak. A water footprint model for the Tetra Pak cartons is presented.

When determining the green water footprint within the Tetra Pak value chain the choice of calculation method is of utmost importance. The difference between the gross green water footprint and the embedded water footprint is observably large. This is one of the major findings described in this report. Gaps in Tetra Pak data collection and challenges connected to the water footprint throughout the production processes are discussed with the aim to assess and understand the impact on the environment.

Key Words: Water footprint; Tetra Pak; carton package; embedded water;

GLOSSARY

Direct water - The water used in a direct and obvious way during production processes.

End-use water footprint - The amount of freshwater use inherently associated with the consumption of the producer's products by others. For example, the freshwater used to dilute pollutants in waste water to meet quality standards.

Evapotranspiration - The loss water from the soil through both evaporation and transpiration from plants.

Gross Green water - the total green water used for crop evapotranspiration.

Indirect water - The embedded water which is used in the supply-chain to produce raw materials.

Net Green water - the difference of amount of water used between the crop evapotranspiration and the natural evapotranspiration.

Operational water footprint - The amount of freshwater used to produce the products in all the producing processes.

Product water footprint - The total volume of freshwater that is used directly or indirectly to produce the product.

Supply-chain water footprint - The amount of freshwater used to product all the products and service that form the input of production of a certain business products. For example, the indirect water which used for the raw materials.

Virtual water (VW) - the amount of water used to produce a product.

Water consumption - Consumptive water use. Water abstracted which is no longer available for use because it has evaporated, transpired, been incorporated into products and crops, consumed by man or livestock, ejected directly to the sea or into evaporation areas or otherwise removed from freshwater resources.

Water footprint (WF) - An indicator of water use that looks at both direct and indirect water use by a consumer or producer. A water footprint refers specifically to the type of water use and where, when and how the water was used.

Water scarcity - A concept describing the relationship of water between demand and availability. It occurs when the annual water supplies drop below 1,000 cubic meters per person per year.

Water stress - A concept describing the relationship of water between demand and availability, it calls "water stress" when the annual water supplies drop below 1,700 cubic meters per person per year in a country or region.

Water use - Use of water by agriculture, industry, energy production and households, including in-stream uses such as fishing, recreation, transportation and waste disposal.

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1. INTRODUCTION

1.1. BACKGROUND

Water is one of the most important natural resources on our planet and a fundamental element of life whose preciousness requires diligent management. Apart from this fact, people use water for other activities such as cooking, drinking and washing but even large amount for producing things such as food, cloths, papers etc. Only 2.5 percent of the total amount of water is freshwater and only 1 percent is easily accessible as ground or surface water. The increase in population, social and economic activities in world during the past decades has affected the availability of world freshwater resources (Postel et al., 1996).

Freshwater of good quality is important and necessary for human societies and natural ecosystems. The recent increase in the use of freshwater as a result of human activities has lead to serious water scarcity in many regions (Gerbens-Leenes P and Hoekstra A, 2008).

Freshwater is one of the basic ingredients for the operations in many companies. The failure to recognize the importance of freshwater in businesses by many companies has lead to increase in risks such as damage to the corporate image, threat of increased regulatory control, financial risks caused by pollution, or insufficient freshwater availability for operations (Gerbens-Leenes P and Hoekstra A, 2008). Clean water is important for public health and ecosystems. The need to ensure a pollutant free (chemical and biological pollutants) of both surface water and groundwater bodies across the world is required. Surface waters of good quality should provide a measure of healthy ecosystems. Water, like air is considered to be a fixed element of the globe (UNESCO 2009). In a rural world, water had virtually no connection with commerce since water from springs, rivers and river branches, wells and cisterns was available at little or no cost (UNESCO 2009). But in the recent time many companies and organizations have recognized the importance of water to their businesses and start encouraging the improvement and sustainability.

Because the distribution of freshwater is not even across land surfaces, since there are a number of heavily populated countries located in arid lands where freshwater is scarce. For instance, countries like Singapore, China and India etc are considered as water-poor countries while countries like Sweden, France etc are water-rich countries. Having many factories and companies in the water-poor countries may lead to water shortage or scarcity in future if proper measures are not taken.

1.2. ABOUT TETRA PAK

Tetra Pak is a multinational food processing and packaging company that develops, produces and markets complete processing, packaging and distribution system for food stuffs. The motto of this company is “protect what’s good”.

Already a world leader in the liquid food processing and packaging field, Tetra Pak is founded by Ruben Rausing and Erik Wallenberg in 1951 in Lund of Sweden, today Tetra Pak has expanded its business including ice-cream, juice, cheese, dry food, fruits, vegetables and pet food different kinds of products which much more than liquid foods. Tetra Pak is one of three independent industries which belong to the Tetra Laval Group which also consists of two other companies: Sidel and Delaval. The activities of the Sidel Group are mainly focusing on packaging lines for liquid food packaged in three main types of containers, namely glass bottles, plastics bottle and drink cans. Delaval Group is also making and selling daily farmer equipments, like milk and animal husbandry. Altogether, there are close to 30,200 employees in Tetra Laval Group, out of which Tetra Pak operates with 21,640 employees in over 150 countries around the globe (Tetra Pak, 2009).

Tetra Pak produce both aseptic and non aseptic carton packages. The first Tetra Pak package was in the shape of a triangular pyramid which was launched in 1953, it was using a system of plastic and aluminum coated paperboard combined with an aseptic filling system. Today it is called Tetra Classic Aseptic.

Tetra Brik is a rectangular cuboid carton which introduced in 1963 by the company. Also, after Tetra Classic Aseptic and Tetra Brik Aseptic package, other packaging formats such as Tetra Wedge Aseptic (wedge shaped), Tetra Prisma Aseptic (round octagonal shaped), Tetra Fino Aseptic (pouch shaped) and other types. The non aseptic packaging systems including Tetra Rex (gable top), Tetra Top (paper and plastic moulded in one) and the Tetra Recart (Wiki, 2009) (see Figure 1).

Tetra Pak packages, from left: Tetra Rex, Tetra Top, Tetra Fino (in front), Tetra Gemina, Tetra Recart (in front), TetraWedge (in front), Tetra Prisma, Tetra Brik and Tetra Classic (in front).

Figure 1 Tetra Pak packages (Tetra Pak, 2009).

1.3. OBJECTIVE

The overall objective of this thesis is to determine the water footprint of Tetra Pak carton economy beverage portfolio. The specific objectives include:

- To provide an overview on the concept of Water footprint.
- To determine the Water consumption and Water use along the Tetra Pak value chain of beverage carton starting from raw materials to filled products.
- To decide the important parts of water footprint in this analysis.
- To develop a model based on available data and connection of each process.
- To identify gaps in Tetra Pak data collection and discuss challenges, potentials and improvements.

2. LITERATURE STUDY

2.1. Water stress and water scarcity

Nowadays, parts of many large countries, such as India, China, and even USA, are facing water stress or water scarcity (see Figure 1). In 2025, around 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the people all over the world will be under water stress conditions (Samuel T. L. Larsen, 2009).

"Water scarcity and water stress are concepts describing the relationship of water between demand and availability." (Len Arblams, 1997). They occur when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use (UNEP, 2009).

When the annual water supplies drop below 1,700 cubic meters per person per year in a country or region, it is said to experience "water stress"; at levels between 1,700 and 1,000 cubic meters per person per year, there will be periodic or limited water shortages. When it drops below 1,000 cubic meters per person per year, the country faces "water scarcity" (Samuel T. L. Larsen, 2009). For example, a developing country with either a high industrial demand or one depending on large scale irrigation will be more likely to experience water scarcity, like India. At present, 19 major Indian cities already face chronic water shortages, and in 2025, the whole country will face the water-stress category because the increase of population, speed up of urbanization and other factors (The Population Information Program, 2009) (see Figure 2).

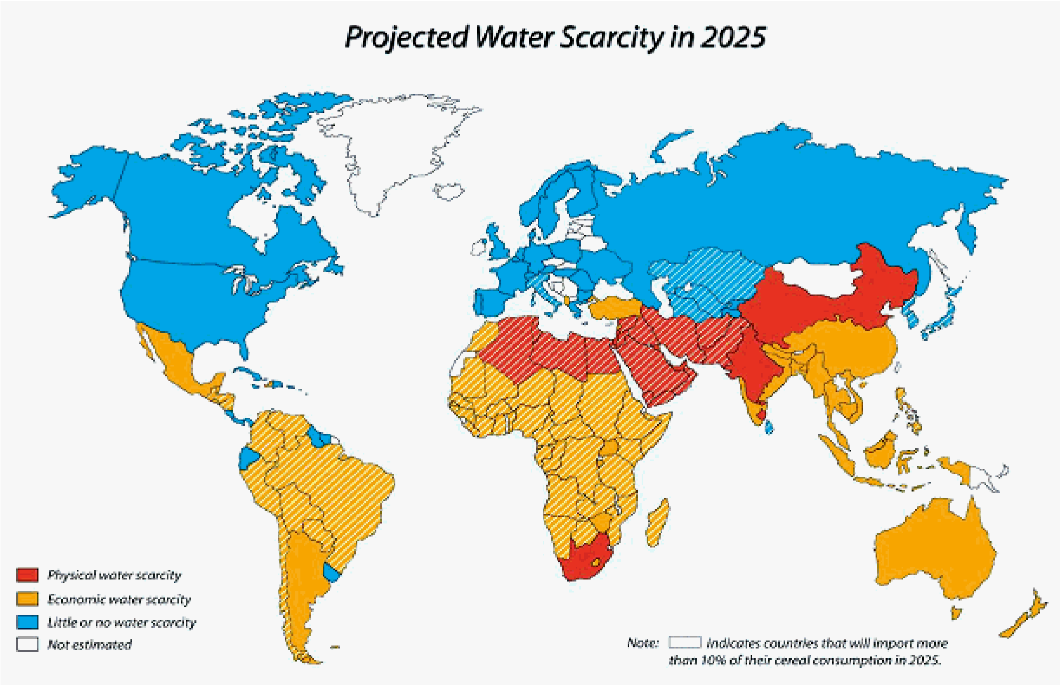

Figure 2 Water scarcity indicator (WSI) 2025 taking into account Environmental water Requirements (IWMI, 2000).

2.2. Virtual water

Water is needed in production of goods and services. Virtual water is defined as the amount of water used to produce a product. The term “virtual” is used since the amount of water contained in the product can be negligible compared to the amount used in the production (Chapagain and Orr, 2009).

For example, to produce 1 kg of cheese 5 m^3 of water is required and for 1kg of beef on average 16 m^3 of water is required (Hoekstra A Y, 2003). Due to large distance and cost, trading of real water between water- rich and water-poor countries is generally impossible but trade in the form of water-intensive products is realistic and common (see Figure 3). With virtual water trade some countries support other countries water need (Hoekstra A Y, 2003). Virtual water trade is one of the way through which countries affect the water system in other parts of the world (Hoekstra A Y, 2002). According to Hoekstra & Hung, “recent research shows that the impact of global trade on regional water system is at least as important as the impact of the climate change on regional water system.” Import of water-intensive products (virtual water trade) can also be seen as an alternative way of relieving pressure on water resource of importing countries (Hoekstra A & Hung P, 2003). According to Hoekstra, “dominant virtual water exporters are the USA, Canada, Australia, Argentina and Thailand while countries with a large net import of virtual water are Japan, Sri Lanka, Italy, South Korea and Netherlands.” (Hoekstra A, 2003).

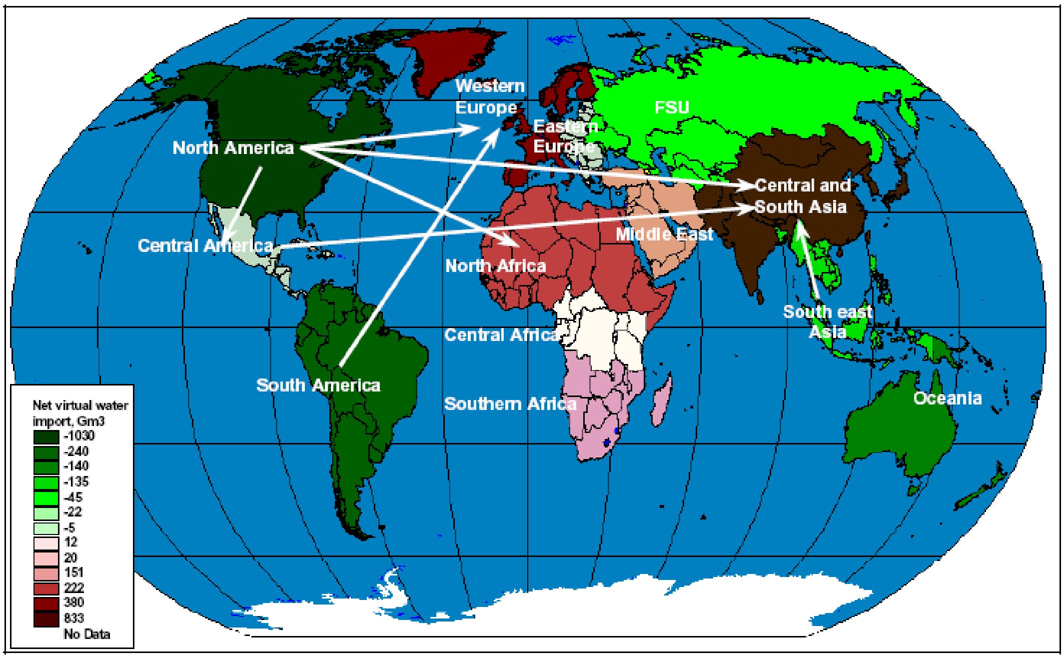

Figure 3 Virtual water trade balances of thirteen world regions over the period 1995-1999. Green colored regions have net virtual water export; red colored regions have net virtual water import. The arrows show the largest net virtual water flows between regions (>100 Gm3) (Hoekstra A Y, 2003).

2.3. Water Footprint

In the past few years the concept of the "water footprint" has started to gain recognition within governments, non-government organizations, business and media as a useful indicator of water use (Hoekstra.A.Y, 2008).

Water footprint can be defined for nation, country, business and products. To produce one type of product more water is needed than the water embedded in it. For example, to produce 1 kg of beef need 16,000 liters of water. And to produce a cup of coffee requires 140 liters of water. Meanwhile, the water footprint also differ from country to country for example: In China, the water footprint is about 700 m^3 per year per person, while it is 1150 m^3 in Japan (WFN, 2008).

2.3.1. Definition of water footprint

Water footprint is defined as an indicator of water use that looks at both direct and indirect water use by a consumer or producer. A water footprint refers specifically to the type of water use and where, when and how the water was used. The root of water footprint analysis lies in the exploration of the global dimension of water as a natural resource (Gerbens-Leenes.W et. al., 2007). The aim was to be not limited with the fact that water resources management is generally seen as a local issue or a river-basin issue at most (Hoekstra, 2008). For instance: similar to the virtual water business between different countries. A product which is produced in China and transported to another country like Sweden, at the same time, the water footprint of this product is expanded from China to Sweden. The global dimension of water resources management and the relevance of the structure of the global economy have been ignored by most of the water science and policy community (Hoekstra, 2006).

A water footprint is more than a figure for the total volume of water used, it refers specifically to the type of water use and where the water was used; it can also measure roughly the times when the water was consumed in different processes. For the impact assessment, it is also useful that one explicitly shows the blue, green and grey elements (these three elements will be explained blew) of the water footprint of a product, because the impact of the water footprint will depend on whether it concerns evaporation of abstracted ground water, evaporation of rainwater used for production or pollution of freshwater (Hoekstra and Chapagain, 2008). The impact of the water footprint of products will depend on the vulnerability of the local water system, the actual competition over the water in these local system and the negative externalities associated with the use of the water (Hoekstra and Basic, 2008).

Water footprint includes three elements: consumptive use of rain water bounded in the soil (green water); consumptive use of water withdrawn from groundwater or surface water (blue water) and pollution of water (grey water), associates with the production of goods and services. It is calculated as the volume of water that is required to dilute pollutants in waste water to meet quality standards.

The components of the water footprint of a product can usually be divided into three parts: The supply-chain water footprint, the operational water footprint and the end-use water footprint (see Figure 4).

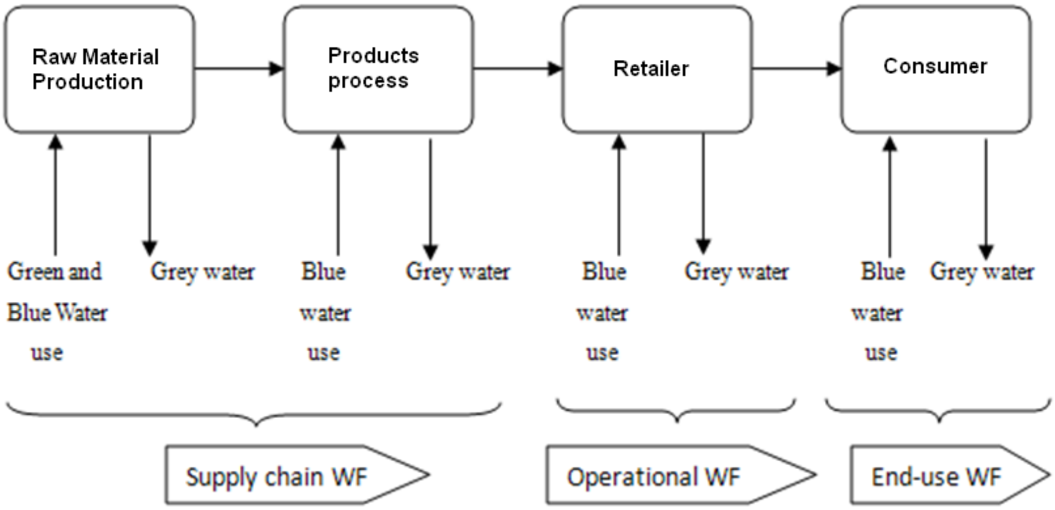

Figure 4 General idea of the types of water involved in the water footprint (Based on Hoekstra, 2008).

For a crop's water footprint (see Figure 5), the supply-chain water footprint is the water use in the producer's supplier, can be considered as indirect water use which mainly is green water and also an amount of blue water is used (e.g. pumping water from river to irrigate crops). Indirect water use means the embedded water which used in the supply-chain to produce raw materials. This step generally does not lead too much grey water.

The operational water footprint is the direct water use by the producer which mainly includes the blue water from groundwater or surface water, and grey water which is used during the processes. Depending on the products, green water can also be a small part of it.

The end-use water footprint is the water use inherently associated with the consumption of the products by others, it can be considered as direct water but mainly in form of grey water. Compared to other components, the volume of this part is usually small, so it can often be ignored.

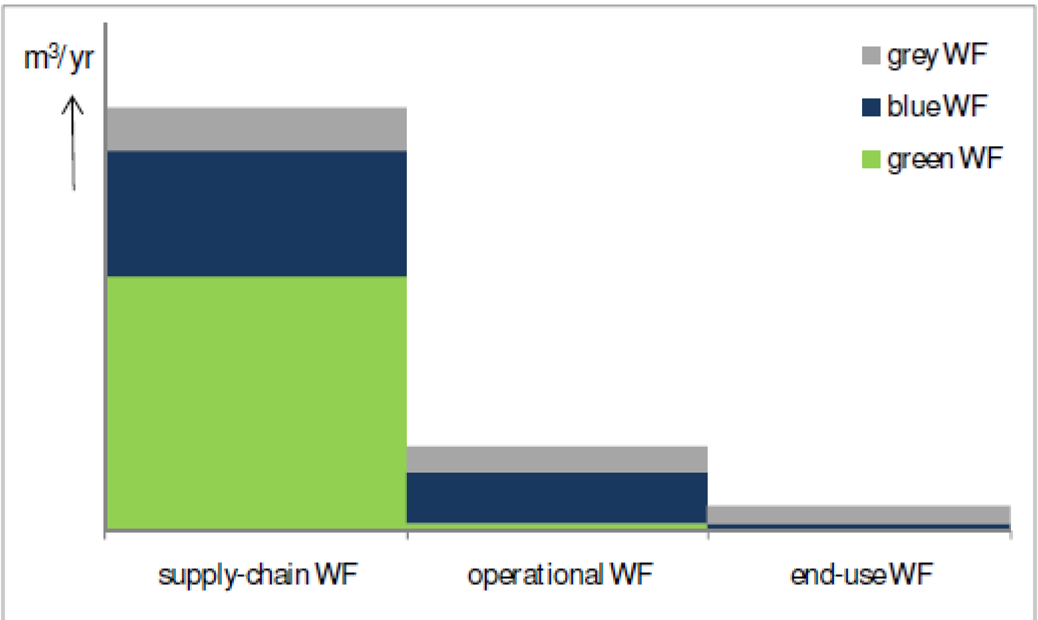

Figure 5 The components of the water footprint of a crop product (Gerbens - Leenes.W et. al., 2007).

2.3.2. Green water and Blue water

The difference between "green" and "blue" resources is the point of origin. The freshwater in aquifers, lakes and rivers is referred to as "blue water", while "green water" water is bound in the soil and plants and released by evapotranspiration (see Glossary ii) and returned to atmosphere. Blue water can be transported and is therefore the only source for drinking water. Green water can not be transported since it is bounding in the soil. For example, between rain-fed agriculture and irrigated agriculture of crop production, there is a significant difference on the opportunity cost. Green water usually has a lower opportunity cost than the Blue water, since the Blue water is usually transported from river, lake or groundwater for irrigation by pumping and using other ways or tools (Lena.H et.al, 2007).

2.3.3. Gross Green water and Net Green water

Since water used by evapotranspiration has been occupied main part of total water used, especially for the crop products of the supply chain, some raw materials and product industries (e.g. paper producing company, food company), challenge the difference between the substantial green water used by the natural vegetation and the amount of green water used by the raw materials. Their arguments go as follows: vegetation consumes a certain amount of water and this amount does not change if the material is used for production of goods or simply left to grow. The definition of “Gross Green water” is the total green water used for crop products. So the standpoint of “Net” Green water has been indicated. A “Net Green water footprint” is the difference of amount of water used between the crop evapotranspiration and the natural evapotranspiration (WWF, 2009).

“Embedded water” also is a point of view needs to be considered. Because embedded water in the raw materials taken by the industries is the actual part take away from sources.

2.3.4. Grey water

Grey water is considered as indirect water consumption used to dilute a pollutant; it is generally seen as a part of Blue water or Green water if the pollutant is diluted by rainfall directly (WWF, 2009). In the broad picture, Grey water is the amount of water which is associated with the production of goods and services, and required to dilute pollutants in waste water to meet quality standards (WWF, 2009). Also it includes the environmental ability, which is accounting of impact of pollution on environmental resources, for example, a river as an environment has its ability like self-purification to accept the wastewater and dilute it until meet the acceptable standard. But it is too difficult to find out the actual quantitative data about the ability, normally it will be ignored (WWF, 2009).

2.4. Water use and Water consumption

About 85% of the global water used by humans is related to water use in agriculture, about 10% to water used in industry and 5% to water used by households (Gerbens-Leenes.W et. al., 2007). The way of defining these three elements of water footprint (Green water, Blue water and Grey water) is mainly based on the sources of the water used and what happens to the water after the process, in other words **where** is the water from and **where** is it going.

Compared with the water footprint of supply-chain, the volume, quality, timing and types of freshwater used in the operational part is much easier determined., but what the water is used for, and which part is related in the entire operational process, these questions are need to be found out specifically. And as an element of water footprint, this is mainly about **How** is the water used. Here as a different point of view to define the types of water footprint, the idea of determining water use and water consumption has its own significance to be drawn out.

Water use – Use of water by agriculture, industry, energy production and households, including in-stream uses such as fishing, recreation, transportation and waste disposal (UNEP, 2009). In the industry processes, it refers to the total amount of freshwater used which includes water that may return to the source, like the water used in a recycling system, or in a hydraulic power system (GEMI, 2002).

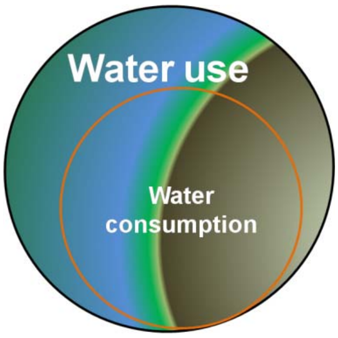

Figure 6 Water use, water consumption and Green, Blue, Grey water.

Water consumption - Consumptive water use. Water abstracted which is no longer available for use in the local system because it has for example evaporated, transpired, been incorporated into products and crops as embedded water, consumed by man or livestock, ejected directly to the sea or into evaporation areas or otherwise removed from freshwater resources (UNEP, 2009).

So water consumption commonly refers to the portion of water used that cannot return to the same source or which is not able to be reused in the local area without it being treated (GEMI, 2002).

In the water use all the three components (Green, Blue and Grey water) in the water footprint can be included, the same three components are also present in water consumption, but the relationship between them is almost certainly not the same (see Figure 6).

2.5. LCA

Life Cycle Analysis (LCA) is the one of the easiest ways to assess the impact of a product on the environment (Chapagain and Orr, 2009). It assesses both potential and environmental impacts associated with a product, process, or service. Life Cycle Analysis studies report the total amount of water used during the production system starting from raw materials to waste management (U.S Environmental Protection Agency, 2009). But, such studies do not state the forms, also the source of water and the way in which water leaves the product system (Llorenç Milà i Canals et al, 2008). And this is one of the reasons why water has not yet been properly assessed in LCA.

Life Cycle Analysis (LCA) and Virtual Water (VW) are analysis tools that have been used to measure amounts of water used in the production of various products. Although both methods do not emphasize on the problem of water scarcity, shortage and opportunity cost of water during the production (Llorenç

Milà i Canals et al, 2008)

2.6. Global Organizations

The concept of water as an environmental issue is still evolving and is on a much more primitive stage compared to the carbon footprint. It is still gaining recognition of government, non-governmental organization, businesses and companies. Organizations and initiatives currently interested in the concept are trying to create awareness about it and also develop tools capable of showing the impact water issues have and will have on society. Below you will find a summary of organizations and initiatives focusing on sustainability.

Water Footprint Network (WFN) is a non–profit organization formed by stakeholders in water resources management from businesses, government agencies, non-governmental organizations, civil society and academia. Their mission is to promote the transition to sustainable, fair and equitable use of freshwater globally. This is done by developing methods and tools, providing meetings, education publications, research and development, promoting water foot print awareness and supporting government bodies, international institutions, non-governmental organizations and businesses (WFN 2009).

World business council for sustainable development (WBCSD) is a CEO-led, global association of some 200 companies formed basically for business and sustainable development. Their mission is to support business leadership to participate for change toward sustainable development. Some of its objectives are to be a leading business advocate, to participate in policy development and to contribute to a sustainable future The WBCSD has developed a global water tool for the companies and stakeholders that need to understand the water issue in their operational area and at the same time their supply chain. The tool aims to provide an answer to the following questions; “how many of your sites are in extremely water scarce area, which sites are at greater risk, how will that look in future, how many of your employees live in countries that lack access to improved water and sanitation, how many suppliers are in a water scarce area now and how many will be in future?”(WBCSD, 2009).

Global environmental management initiative (GEMI) is an organization of leading companies which aim to promote the development of global environmental, health and safety excellence. Their mission is to help business improve their global environmental, health and safety performance, shareholder value and corporate citizenship. GEMI has developed two water sustainability tools namely; “connecting the drops” towards creative water strategies (a water sustainability tool) and “collecting the drops” (water sustainability planner), they aim to address the challenges and opportunities of water sustainability and can also be used by a company to access and evaluate their performance, opportunities, goals and progress against objectives (GEMI 2009).

Alliance for water stewardship (AWS) aims to establish a water stewardship enterprise to recognize and reward water management and usage that is both socially beneficial and environmentally sustainable. Their mission is to encourage responsible use of freshwater both socially and environmentally sustainable (AWS 2009).

Water stewardship initiative (WSI) is an independent organization which aims to unite a group of stakeholders to share in development of global water stewardship principles and practices (WSI 2009).

European water partnership (EWP) is a non-profit organization which helps to coordinate initiatives and activities in international water issues and to promote the international recognition of European expertise related to water. Their mission is to initiate, support and enforce all actions and projects that will help to achieve the aim of the water vision for Europe (EWP, 2009).

Others

There are other organizations, institutes supporting and promoting water related issues, such as The CEO water mandate, Global reporting initiatives, United nation, European union, Stockholm international water institute, Pacific institute. Their aim is to provide information on water issues and support water related research and projects.

3. METHODOLOGY

A research approach refers to the approach or methodology that has been selected to conduct the research. It usually involves the selection of research questions, research methods and conceptual framework. Research is usually performed using three main approaches or methods namely quantitative approach, qualitative approach and mixed methods approach.

3.1. Quantitative approach

"Quantitative research is defined, not just by its use of numerical measures but also that it generally follows a natural science model of the research process to establish objective knowledge (that is, knowledge that exists independently of the views and values of the people involved)" (Christine S. et al, 2004). Quantitative research places the emphasis on measurement when collecting and analyzing data and it usually employs highly structured procedures during the research process (BHP Information Solution, 2009). Data are collected using sampling techniques and structured questionnaires and carried out in various forms such as face to face interview, by telephone, by email, via web-surveys or by post (BHP Information Solution, 2009).

3.2. Qualitative approach

This method aims to determine people's feelings and purpose of their feelings (DJS Research Ltd, 2009). It employs the use of questionnaires to get necessary information, information is usually collected in form of open-ended observation, interview or group discussions and it take place in a natural setting(DJS Research Ltd, 2009). It aims to "study things in their natural setting, attempting to make sense of , or interpret, phenomena in terms of the meanings people bring to them," (Denkin NK et al, 1994). The mode of collecting and analyzing data in the qualitative method depend on the meaning (word) instead of frequencies and distributions (Christine S. et al, 2004). Qualitative researchers get their results based on research participants view (Christine S. et al, 2004).

Researches usually go to the site to conduct the research. Qualitative research may have pre-defined questions which can then be addressed in quantitative studies (Black N, 1994). Qualitative method uses induction rather than deduction in its approach, that is, it generates theory from interpretation of the evidence, although against a theoretical background (Christine S. et al, 2004).

3.3. Mixed methods approach

This method encourages the use of both qualitative and quantitative research within a single study. However, most of research and evaluation studies make use of mixed methods. Mixed method approach combines both the strengths and limitations of qualitative and quantitative methods (Christine S. et al, 2004). Combining both methods gives more useful and accurate results (DJS Research, 2009).It seems to be a more concise approach in answering research questions, since part of the questions are open and complex and can be difficult to be answered using a single method (Christine S. et al, 2004). Mixed approach shows the strengths and weaknesses of each approach. Both quantitative and qualitative methods are two legitimate ways to conduct a research. Everet and Louis (1981) clarify the assumptions that ground each by distinguishing two research stances: "inquiry from the outside", often implemented via quantitative studies and "inquiry from the inside" via qualitative studies. These approaches depend on the researcher's experience, knowledge on the subjects, and physical involvement in the setting. (G. Goethals. et al, 2004).

A mixed method was used in this project that is a combination of quantitative and qualitative methods. Five parts were considered in this project namely (I) raw materials, (II) converting, (III) filling, (IV) processing and (V) products. A mixed method was used since some process requires qualitative approach while others requires quantitative approach or rather combination of both methods. Quantitative method was used in raw materials, filling and products process while qualitative was used in processing for the converting process both methods were used.

I. **Raw materials**

The aseptic beverage carton is made of three different types of materials, namely paper, plastic and aluminum. The quantitative approach was used to obtain information and data on raw materials. For the paper two processes were considered in calculating the water used in production of paper. The first part was calculation of the water volume needed by trees to grow and another part was the calculation of water used in the production of paper. This procedure was used because it gave more information on the water footprint of paper. Since large part of water (green water) was used during the growing of tree. Data used was limited to the information obtained from two sources. Aluminum being part of raw material for carton package was considered. Each process in production of aluminum was taken into account on obtaining information. Considering each process provide more detail information on water used during the production of aluminum. The data was limited to one source which based on the European Aluminum Association report. Plastic is one of the raw materials used in production of carton packages and the most commonly used type is low density polyethylene (LDPE). It involves several processes (see Figure 17) and water used or consumed in each process was considered. The data and information used was based on recent research by Borealis Group.

II. **Converting process**

For this process both methods were used. The first step was visiting the local converting factory in Lund, Sweden, to understand how water was consumed or used. Based on the information, questionnaires were designed and sent to other converting factories, the aim was to have multiple sources of information relating to the questions; volume, how, where and what type of water was used. The first questionnaire (see appendix-A, page56) which contained many questions was sent to the local converting factory. After feed back and discussion some questions were removed (quantitative approach). This was done as a test run before the real questionnaire. The second version of the questionnaire (see appendix-A, page56) was designed. Face to face interview was also used in collection of data (qualitative approach). This version of the questionnaires was sent to three converting factories and the feedback was used in converting factory part of the model. A constraint in this part was that the questionnaire focused on three out of twenty seven converting factories. Three converting factories were selected based on the factories that have been interested in water issues before.

III. **Filling process**

Quantitative method was employed in this process. The focus was on Tetra Classic Aseptic, Tetra Fino Aseptic and Tetra Wedge Aseptic three series and 12 different types of package. From the types of package, information about the capacity and water used by 6 different types of filling machine was obtained (see appendix-D, Table 18). Filling machine Tetra Pak A1/mini is for the TCA 20B (Tetra Classic Aseptic 20ml base) package. TPA1TCA (Tetra Pak A1 filling machine for Tetra Pak Classic Aseptic packages) is for other 5 types of TCA packages which including TCA 200B, TCA 65S, TCA110S, TCA150S and TCA 200S (B is the abbreviation of base and S is slim). TPA1TFA is meaning Tetra Pak A1 filling machine for Tetra Pak Fino Aseptic packages which including TFA200, TFA250 and TFA500. Meanwhile, TFA/3 filling machine is only for TFA1000 (Tetra Fino Aseptic 1000ml package), TBA/19 is for Tetra Wedge Aseptic 125 ml slim package(TWA 125S) and TBA/20 is for TWA 200S.

IV. **Processing process**

This process depends on the products and consists of many products like cheese, ice cream, beverages, prepared food etc, but the research focus only on milk and juice. The milk and juice were selected because it is most common products packed in carton packages. Qualitative method was used in obtaining information on this part, by conducting a face to face interview with a person from processing solutions department. Based on the interview, it was noticed that this process varies depending on the products and countries.

V. **Product process**

The research interest was limited to two types of products namely milk and juice. Quantitative method was used in collecting information on this process. For the milk product it was found that milk produced by a cow depends on the water in-take of the cow and the input used on this process was based on this assumption. Limitation to this part is that food taken by the cow (like grasses) was not considered which contain water as well and also information was taken based on public sources. For the juice, two steps were considered for example apple juice; the first step is from tree to apple fruit then from apple fruit to apple juice. Water used in each of the step was noted and also the data was limited to at least two sources.

4. MODELING

4.1. Modeling flow chart

The model will give an overview of how water is used when making a Tetra Pak product. It will include the entire value chain of a Tetra Pak customer giving the proper perspective for how much water is used enabling Tetra Pak to better understand the impact of its product on local water system.

To be able to calculate the Water footprint of the Tetra Pak Carton Economy's beverage portfolio, the understanding of Tetra Pak value chain and how water is consumed in it is necessary since it will form the basis from which the model is developed.

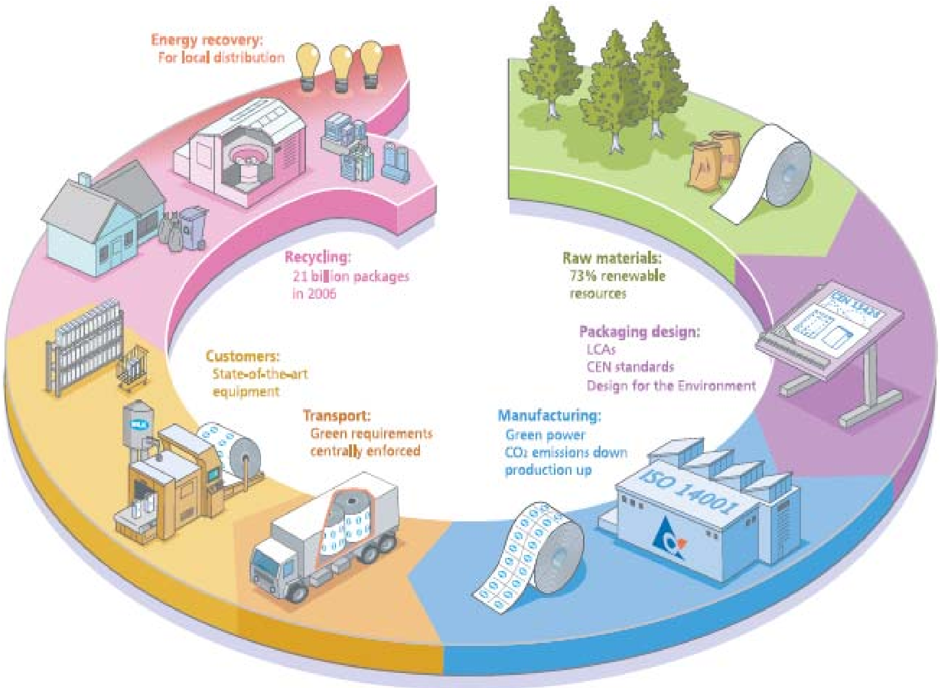

Figure 7 Environmental performance of Tetra Pak value chain. (Tetra Pak, 2007)

The Tetra Pak value chain starts with (see Figure 7), wood and other raw materials (bauxite, ethylene), these are processed in several steps and delivered to the converting factory, as paper, aluminum and plastic. In the converting factory raw materials are converted and laminated to package material. The package material is then transported to the customers were they are used to make packages.

However the total Water footprint of a Tetra Pak package is more complex than this value chain implies. Apart from the package there is also the product contained and the process used to refine it. This thesis will focus on the total product water footprint of a Tetra Pak package, defined as the total volume of water that is used directly or indirectly to produce the packages and the containing product including water that is either evaporated or polluted. Thus, this thesis not only Tetra Pak supply chain but also the supply chain of a Tetra Pak customer. This model will include the total volume of freshwater that is used from the raw material through the various steps of the different production chains all the way to the consumer.

Hence, based on this environmental performance of Tetra Pak value chain and basal knowledge, a flow chart of the model is created (see Figure 8).

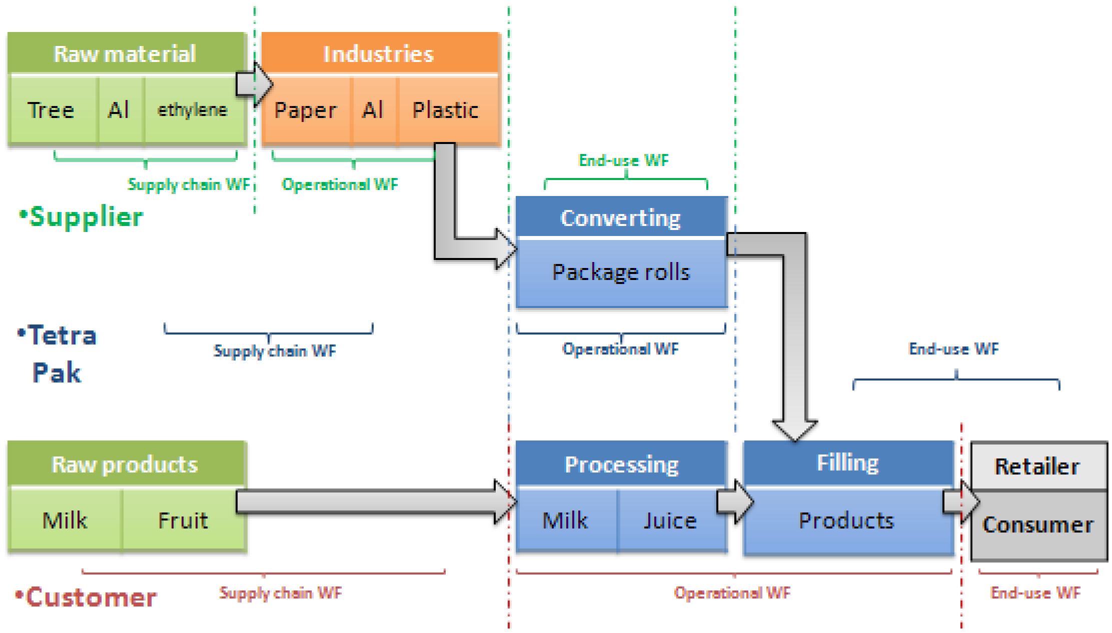

Figure 8 A flow chart of water footprint modeling in Tetra Pak.

This flow chart illustrated three different points of view of water footprint. In the Supplier's view, the Supply chain Water footprint will be the water used by the raw materials primarily the trees (bauxite mining for the Aluminum and 99.9% pure ethylene for the plastic as original sources do not need any water use before processing); the Operational Water footprint will be the water consumed during refining and processing of the raw material, to the supplier Tetra Pak is a part of the End-use WF.

From Tetra Pak's view, both of raw materials and industries which process raw materials are a part of the Supply chain Water footprint. The process at the converting factory is treated as the Operational Water footprint; the water used the filling process as well as by the consumer is considered as End-use Water footprint.

From the customer's view, the Supply chain Water footprint will be the total Water footprint of the customers supply chain, including raw materials in the form of wood, aluminum, plastic as well as the product and the refinement of these. The operational Water footprint includes the processing of the product and the filling.

Therefore, depending on whether the Water footprint is based on the raw materials producer, Tetra Pak or the Tetra Pak producer the three components of Water footprint, Supply chain Water footprint, Operational Water footprint and End-use Water footprint will be different. This model will look at all of these processes, with a focus on the Tetra Pak packages.

4.2. Input frame and output frame

4.2.1. Software application

This model will be created on Microsoft Excel. Excel is one of the most popular software in use today and a powerful tool, this spreadsheet program has many different functions enabling database, calculation, graphs, and statistical analysis. It will be easy for people to read, use and update or append to other use like website.

4.2.2. Input frame

The input will be divided into two parts. The first part is for the users who want to find out water footprint information of their packages to input their information, and then this information is used to search other factors. It will consist of only three choices: **Types of package**, **Type of product**, and the **Country** (see Figure 9).

Input	
Type of package	
Type of product	
Country	

Figure 9 Input frame in the model

This simplified input data will be used to search the database for relevant factors such as the amount of water consumed during different parts of the process.

This database can be updated by Tetra Pak, to add, amend and update the included factors as more information becomes available. For example, if a new type of package needs to be added into the database, its information should be filled in different cells properly.

4.2.3. Output frame

PACKAGE NAME		Product		Location		Water stress		
Data \ Name				Product	Raw material			
WF	Processing	Filling	Converting		Paper	Al	Plastic	Total
water use								
water consumption								
Green								
Blue								
Grey								

Figure 10 Output frame in the model.

The output will present the information of a single type of package which is selected by the input part, then through the factors matching and calculation in background process. Basically, the output frame is listed into 6 columns which the Water footprint consist of 5 main processes and the total value (see Figure 10).

- At the top, the package name, the Location (**where**) and **Water Stress** situation is showed, to give the general information and idea about if there is any water problem in the region or country.

- Then at the second part, the qualitative method is used, it will show both the volume of Water use and Water consumption as well as the Green, Blue and Grey water used in each process.

- Using the result of the second part, the third part will show the percentages of the Water used in these processes to better understand **How** and **What types** of water that is used. This will be illustrated by graphs.

- The model can be used to compare different packages to better understand any differences. It can also be used to compare with other products, like for example PET bottle.

4.3. Boundaries and limitations

The difficulties encountered during this research work should be highlighted. Since, the concept of water footprint is still evolving and is on a much more primitive stage compared to the carbon footprint, there were challenges in finding relevant data base on previous studies.

The major challenges were encountered during the data collection, mainly on the supply-chain calculations parts, hence some assumptions were made. For the operational water footprint there is no uncertainty on the available data, since they are obtained from Tetra Pak database. Otherwise the assumptions and data used give a fairly good picture of the actual result, since it was stated in the sources of information. It is expected that more useful and reliable sources of information and data will be available in the future, as the interest in water footprint keep increasing.

Another aspect of the data issue was dealing with the electricity and energy water footprint, apart from the plastic process, the water footprint of electricity and energy were not considered in this research work. Due to there are no available data or information that can be figured out and also their suppliers of plastic company are from different countries with different sources of electricity and energy. However, in most cases arbitrary assumptions are made which makes it difficult to have confidence in these values. According to Stylianos Katsoufis "the WF network itself recognizes that the energy WF values published in the studies so far performed are rather rough estimates that definitely require further research and review"(Stylianos Katsoufis, 2009). Based on this one could say that the actual water footprint value of supply-chain was cut down for not considering the energy and electricity water foot prints.

This research work follows the water footprint concept as defined by Hoekstra and high priority was given in data collection in order to avoid uncertainty and unreliability on data values. Still on the supply-chain, for the paper as previously mentioned two processes were considered in calculating the water used in production of paper. The first part was calculation of water tree needed to grow and the other part was calculation of water used in the production of paper. Since there is no available data on the water footprint of paper from the paper industry and also since large part of water (green water) was used during the growing of tree.

Based on that some assumptions were made, this report considered the gross green water, net green water and embedded green water of twenty year tree, in order to give a good picture of water footprint of a paper. For the plastic, the data and information used was based on recent research by Borealis Group. It is also important to mention that only two products (milk and apple juice) were considered in this report, which helps to have a good picture of the packages with product. And also in this report data from three converting factories out of twenty seven were used.

Another part that needs to point out is the geographical dimension of supply-chain water footprint. Since the water footprint is geographical explicitly indicator, which accounts not only for the actual volumes of water use but the various locations where the water is used. For the operational water footprint there is no difficulty on that since the company knows the source of water and the consumption units of its factories. For the supply-chain water footprint, it is possible to trace back the location and time but the resources and time does not permit it.

Another part that needs further discussion is grey water. Grey water going by definition is the volume of polluted water, calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains above agreed water quality standards**.** But it is usually difficult by the industries to analyze it using dilution factor, since the water emission vary from country to country.

5. DATA COLLECTION

Data collection is a major part of this project since the Water footprint of the entire process is complicated, due to the variety of use, form and volume in each sub-process.

5.1. Data sources

Data collection is mainly considered into two parts, internal sources from within Tetra Pak and External sources. All of the Package information, Filling machine, converting factory data, processing raw data is supplied either directly by Tetra Pak or by interviews with Tetra Pak personnel, others like raw materials and products are researched from public sources.
Therefore, in main processes, the data collection will focus on finding the relationship between these processes according the Water footprint in this entire processing chain.
Upon that, practical factors like the source of water from, the process of water used for, the water quality and volume requires, the place of output water going to, and also the water issue and environmental situation will be considered and collected in each process.

5.2. Internal data source

- **Package information:**

From Tetra Pak the different types of package's information are collected. Figure 11 shows an example of the layers in a Tetra Pak Aseptic package.

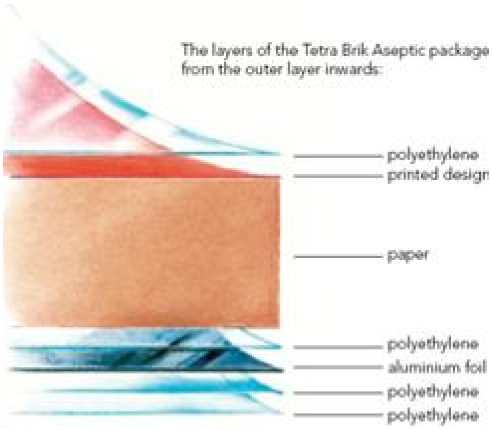

Figure 11 The layers of the Tetra Pak Aseptic package (Tetra Pak, 2009).

Hence, the following package information is including **Package Name**, and its corresponding **Package Area (m^2)**, **Paper Weight (kg/p)**, **Aluminum Weight (kg/p)** and **Plastic Weight (kg/p)**.

This information is then related to other parts of the processes part which means from the inputting to match the factors in each process by finding out the connection between them. For example, if a type of package is selected, it will be matched to the package information, and then from the specific information like Area, Weight, and container Volume to find out difference of water foot print between the different quantity of raw materials used (like paper, Aluminum and plastic) and also in other processes like converting part. The data from the table indicated out that the weight of paper is occupied a high percentage of the total weight of package in each type of package. The difference will be showed late on the outputs.

- **Converting:**

In the converting factory the raw materials; paper, aluminum and plastic is processed to rolls of package material.

For the converting process, a questionnaire letter was designed (see Appendix–A page56) and sent to the three converting factories which are Jurong of Singapore, Izmir of Turkey and Lund of Sweden. These questions are mainly designed to collect specific information and detailed data using the qualitative approach: Water environment (to find out if that region or country has water stress or not), Where the water used is from and how much of it us used as well as what happens after the process (to find out the source and defining three different types of water, also to calculate the water use and water consumption); some of the questions also use the quantitative approach to gain basic knowledge about the water footprint and environmental issues.

From the questionnaire data collection, Jurong of Singapore is facing the water stress problem; Lund of Sweden and Izmir of Turkey do not have this problem. Because of the variety of package rolls produced in the different converting factories the data of water use is not possible to be specify into an exact number, but the **capacity** of MSP (million standard packages) for each converting factory is available. The water consumption is mainly **washing** which depends on the frequency and individual converting factory standards, the water use also includes **cooling** which takes place at a certain time and amount in a closed recycle system, from this background information, the way to calculate water footprint is based on the capacity of MSP (million standard package = 78890 m^2) and the specific area of each package to find out the water footprint for every type of package.

For the Water footprint calculation, the yearly water used is available. In the Jurong converting factory the data is the total water used in the factory, this means that it also includes extra water used which is for example civil construction and personnel's daily use (people washing and toilet). Because this project is focusing on the Water footprint of the Tetra Pak packages, and the extra amount of water used is not proper water consumption for the packages, the data of the Jurong converting factory will be modified by corresponding to the data from Middle East which has the specific data of water used only for the producing process.

According to the definitions of water use and water consumption (see Figure 12), the water used for washing is defined as water consumption because it transports to the wastewater treatment plant afterwards and as the definition of water use, its total volume of water use also includes the cooling water because it is a closed recycle system.

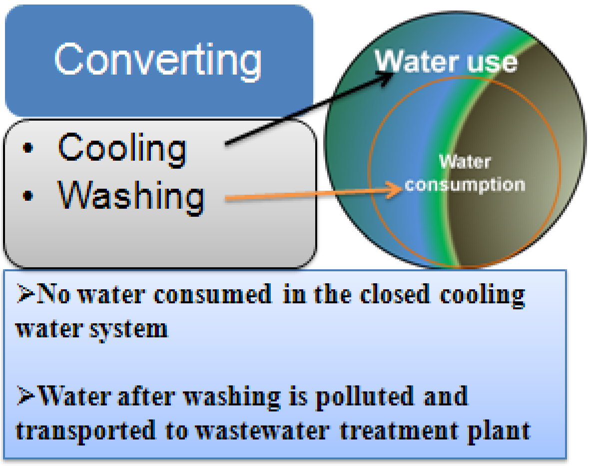

Figure 12 Water footprint of converting process.

➢ **Filling:**

The filling process takes place in the customer's factories.

At the filling part, the types of filling machine can be found according to the package and the corresponding **Capacity (p/h)** as well as the **Cooling (l/h)** water and **Steam (kg/h)** consumption. All of the water used is of drinking water quality and comes from public water supply system like water purification plant. Accordingly the source of water is blue water, and there is no green water involved in this process.

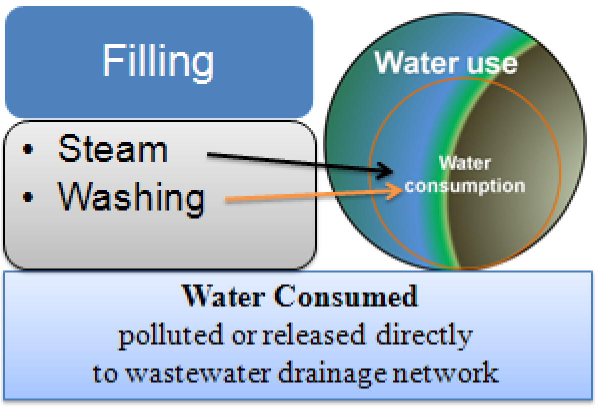

Figure 13 Water footprint of Filling process.

From Figure 13, the water consumption also includes cooling water which is usually released directly without a closed recycling system. Therefore, the water use and water consumption will be the same in this process.

The Water footprint of each type of package is differentiated by which type of filling machine corresponds to that package, each of the three different types of machine has a different capacity, also different cooling and steam consumption.

- **Processing:**

According to the Tetra Pak processing department the processing standard varies from customer to customer, country to country and even from time to time. It depends on how many and what kinds of products the customer is producing, which standard of water qualities is required for the products in that country or region, if there is any recycling system applied as well as what kind of recycling system it is, and also how to they treat the washing water. Due to these uncertainties it was suggested to use the raw data below (see Table 1). In this report only two kinds of product, namely milk and juice will be considered

Table 1 The data of water use in processing part

<table>
<tr><th>Product</th><th>Water consumption (liter water/ liter product)</th><th>Mix water (%)*</th><td rowspan="3">*Mix water (%) means the percentage of water added to the concentrated product</td></tr>
<tr><td>Milk</td><td>1</td><td>0</td></tr>
<tr><td>Juice</td><td>0.8</td><td>70%</td></tr>
</table>

The water consumption shown in Table 1 includes the water used by all the parts of water consumed during the entire processing chain.

5.3. External data source

Raw material

The “Raw material” in this project means the materials provided to Tetra Pak converting factory by the supplier, it includes paper, aluminum and plastic, as well as some other materials which in other processes. These other materials will be ignored due to the small amount water are used in these processes, like for example ink.

- **Paper**

Paper is the main material of the carton package. Two steps are used to find out the water footprint of paper.

1st. Water footprint of the trees growth;

2nd. Water footprint of the paper producing processes in the paper industry.

For the 1st step, these questions were considered:

- How much water does a tree need to absorb daily?

- How many years does a tree need to grow to be available to make paper?
- How much paper can be made from a tree?
- Where does the water come from?

From public sources, it was found out:

Table 2 Water demand of various tree species (Ottawa Forests and Greenspace Advisory Committee, 2009)

Water demand of various tree species		
High demand	**Moderate demand**	**Low demand**
Elm Oak Poplar Willow Silver Maple Manitoba Maple	Cherry Ash Hawthorn Hornbeam Other maples (Sugar, Red) Mountain Ash	Beech Birch Mulberry Cedar Fir Pine Spruce

There is different water demand of various tree species (see Table 2). And it also depends on the soil types, climate, slope direction and other factors. Therefore, the information below should be considered as approximate values only.

The amount of water needed for a young tree maybe only 4 liters per day, but for a fully mature tree it might be up to 900 liters per day (Ted Sammis and Esteban Herrera, 2005). And a mature oak tree may draw up to 200 liters of water or more per day (Jacobo Bulaevsky, 2000). “Large Douglas fir can use up to 3000 liters per day” an answer to the question of “how much is the water consumption of a tree”, and another answer “southern yellow pine dominant large trees can use up to 1200 - 1500 liters per day”. Based on these answers, the water consumption for a tree is cannot be give with high accuracy.

- So, here the water need of a tree is roughly estimated as 700 liters of water per day during its growing period from young till mature and used as an average number.

A tree normally need to grow 10~20years to be harvest enough to make paper (TAPPI, 2001). But other source says it takes from 15 to 80 years (Illinois Department of Natural Resources, 2003).

- Also like the last question, the time for a tree need to be grow enough to make paper is assumed to be 20 years as an average number.

The following discussion will be how much papers can be made from one tree. From the source of American Forest & Paper Association, it assumes that using 100 percent hardwood which is approximately 1000 kilo gram can produce 200 to 500 kg of paper. And some common opinions like "17 trees to make a ton of paper" which means one tree produces about 60 kg paper (TAPPI, 2001) or it takes 63 kg of paper/tree (Green Press Initiative, 2008). Also a calculation table about this question is available from public source (see Table 3).

Because of the similar reason of water need and growing period requirement of tree, the data of amount of paper make from one tree also difficult to be exactly count. So the way to choose data is based on this information and gets the average number.

Table 3 Calculation for how much paper can make from one tree (Hari Goyal and P.Eng, 2009)

Particulars	In Metric Unit
Type of Paper	Copying Paper
Dimension of Single sheet of Paper	A4 (210x297mm)
Weight of Paper	70 gm/m^2
Weight of single sheet	70*0.21*0.297 = 4.366 gm
Type of Tree	Pine
Dimension of tree	25 m high and average diameter is 30 cm
Volume of one tree	3.146*.15^2*25 = 1.7696 m^3
Density of pine (dry weight basis)	600 Kg/m^3
Weight of the tree	600*1.77= 1040 Kg
Yield of pulp (pulp produced/weight of wood)	50%
Pulp Produced	0.5*1040 = 520 Kg
Number of sheets produced	520*1000/4.366 = **119100**

- Here, the amount of paper produced from one tree is 400 kg.

Combine all of the selected data, the water footprint for a tree to grow harvest enough to make paper is calculated, therefore it is about 1.3*10^3 liter/kg (calculation: 20years*365days*700liters of water per tree/ 400 kg paper =12775 liter/kg).

- The source of water is difficult to find out, because it not only depends on the way of paper industry getting trees from, but also relate to the status of forest, if it is an irrigation forest or an original forest. Here the water used for tree growing is all counted as green water for an original forest. So there is no blue water used for tree's growing.

  The Grey water is unable to find out, it is assumed there is no water is polluted during the growth period of trees.

A divergence of opinion about how to calculate the green water is still arguing. For example the discussion about the Net Green water and Gross Green water.

2nd Water footprint in the paper industry

From the main steps in Mechanical pulping processes (see Figure 14), a table of water use information was collected (see Table 4).

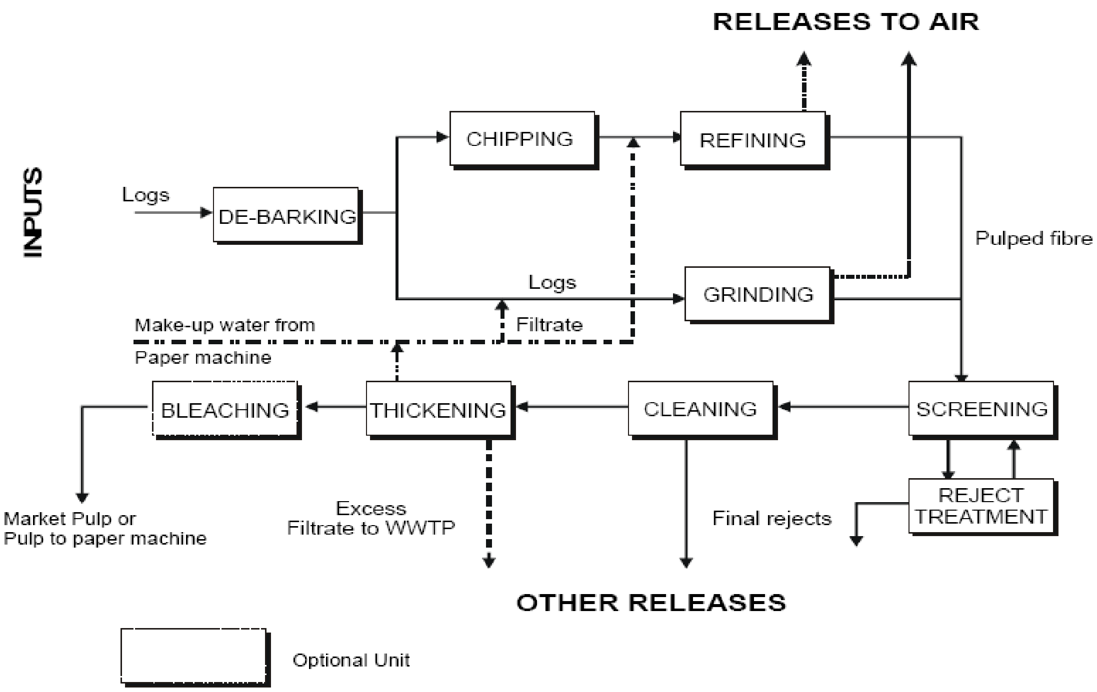

Figure 14 Main steps in Mechanical pulping(IPPC, 2001).

Table 4 The water used for the main steps of mechanical pulping.

Water input	Volume (m^3/t)	Water output	Volume (m^3/t)
Surface water	22	Wastewater flow	14.1
Ground water	4.6	**For Recycling**	**Volume (m^3/t)**
		Cooling water	12

Then the type of Water footprint can be calculated. The results are given Table 3. It shows the different elements of water footprint in mechanical pulping processes.

Table 5 The Water footprint of Mechanical pulping processes.

Type of water footprint	Volume (l/kg)
Water use	26.6
Water consumption	14.6
Green water	0
Blue water	26.6
Grey water	14.1

The Water use is the total water input. Because of closed recycle cooling system (European commission, 2001), the water consumption should be not include the cooling water. Furthermore, because of the water sources, there is no green water, and the grey water is equal to the volume of wastewater flow. And there is 0.5 liters water evaporated during the processes.

Hence the total water footprint of paper raw material from 15 year old trees after processing in the paper industry to be paper is given in Table 6.

Table 6 The Water footprint of paper.

Water footprint of Paper	Volume(l/kg)
Water use	12801.6
Water consumption	12789.6
Green water	12775
Blue water	26.6
Grey water	14.1

- **Net Green water**

From the way to collect data, the Green water which is given above is Gross Green water. As discussed in the literature study, the definition of Net Green water footprint is the difference of amount of water used between the crop evapotranspiration and the natural evapotranspiration (WWF, 2009). Then the number of net green water should be very low for this case.

- **Embedded water**

Compared to the Net Green water, the water embedded in the trees is more reasonable to count and compare with the gross green water. Because the trees are continuing to consume the gross green water all their lives, and water consumed by the evapotranspiration does not lead to any pollution, instead of that, it is a necessary part of water cycle. From the table of water percentage of trees, an average number of water embedded in the tree is 26.63% (see appendix-B Table 16). Then Table 7 will show the water footprint of paper. The average weight of trees is 2000 kg. So the embedded water for a tree is about

500 kg which is 500 liters. So the embedded water for per kg paper is 500/400=1.25 liter water per kg paper.

Table 7 The water footprint of paper by including embedded water.

Water footprint of Paper	Volume(l/kg)
Water use	27.85
Water consumption	15.36
Embedded water	1.25
Blue water	26.6
Grey water	14.1

- **Aluminum**

The data collection is based on the "Environmental Profile Report for the European Aluminum Industry".

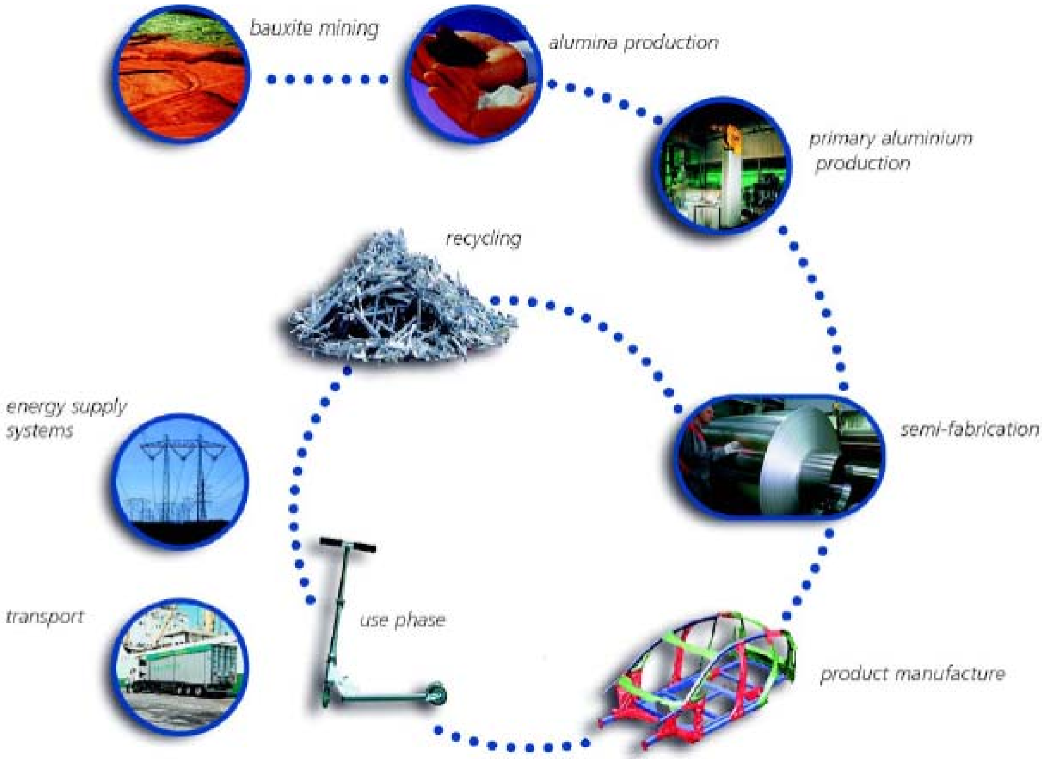

Figure 15 Life cycle of Aluminum product (European aluminum association, 2008).

The Life cycle of an aluminum product includes 7 main steps (see Figure 15). In the Tetra Pak converting factories, the supplied aluminum product is aluminum sheet, so in this case, from bauxite mining until product manufacture, these 5 steps were taken to calculate the Water footprint of aluminum raw material in the supply chain (European aluminum association, 2008).

Bauxite is the main raw material to produce aluminum. After it is extracted from mines and processed into aluminum oxide, it will be processed into aluminum metal by an electrolytic process. Here some raw materials need to be added; the main one is carbon anodes and aluminum fluoride. Then aluminum is alloyed and cast into ingots from the smelters for primary products (see Figure 16). By the rolling, extrusion or product casting processes and cold working at the end or finishing operations, the ingots are fabricated to be wrought aluminum products, after that the aluminum castings are manufactured to be advanced products like aluminum sheets which is the supply material of Tetra Pak converting factory, also at the end it followed by finishing operations (European aluminum association, 2008).

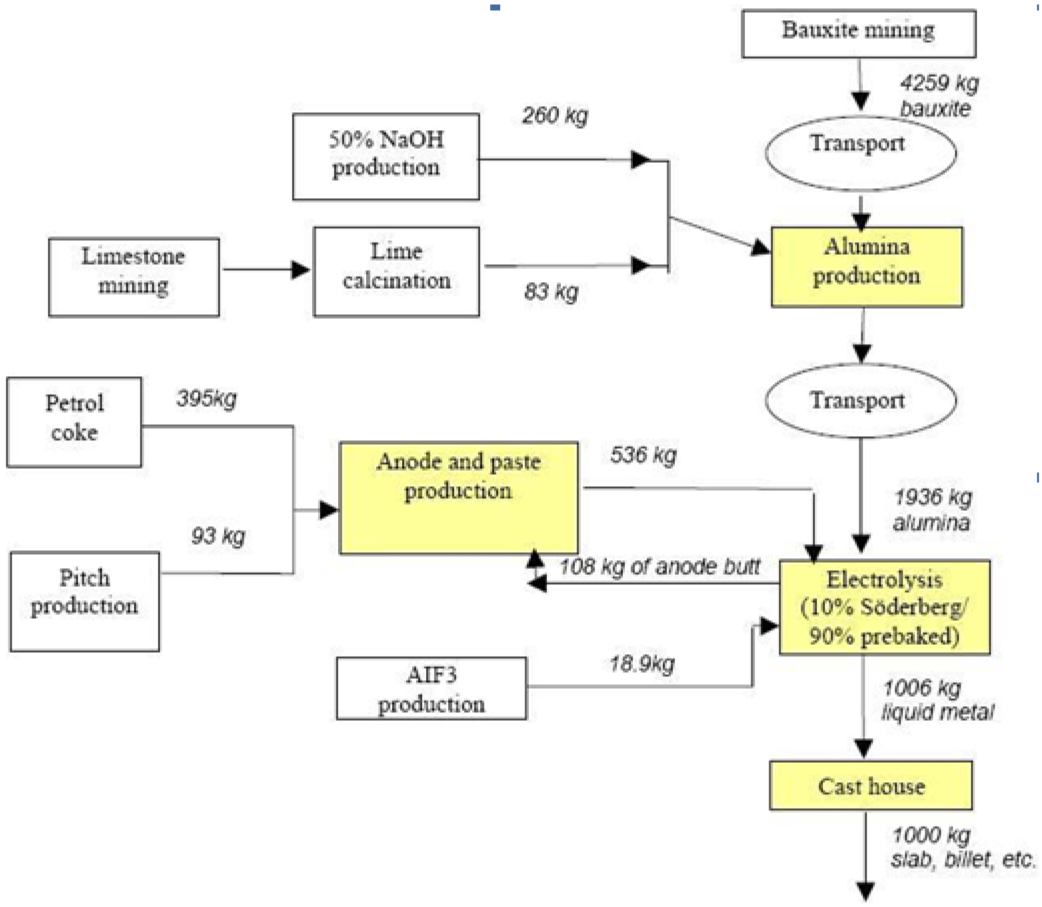

Figure 16 Main processes for primary aluminium production in Europe.

Based on these processes, on water input and output collection is listed to produce 1 ton of product in each steps (see Table 8).

Table 8 The input and output of water used in Aluminum processes.

Primary process	Input water(m^3/t)	Output water (m^3/t)
Bauxite mining	0.5	0.47
Alumina	3.25	1.9
Liquid metal	9.6	9.1
Anode	3	2.3
Slab billet	3.1	2.5
Advanced process	Input water (m^3/t)	Output water (m^3/t)
Aluminum Sheets	10.21	5.8

Because the value of products is reduced from one process to the next process, so the transition of Water footprint volume is needed with the passage of value of products from step to step (see Table 9).

Table 9 The input and ouput water for 1 ton of Aluminum sheet products.

Products	Input water(m^3)	Output water (m^3)
Bauxite mining	1.10	1.03
Alumina	6.26	3.66
Liquid metal	9.51	9.01
Anode	2.97	2.28
Slab billet	3.10	2.50
Aluminum sheets	10.21	5.8
Total	33.15	24.28

The source of water is mainly surface water and it is used for diluting pollutant and cooling which will release to the wastewater treatment plant and sea, so Table 10 list out all of the elements of water footprint about the raw material of Aluminum.

Table 10 The Water footprint of Aluminum.

Water footprint of Aluminum	Volume(l/kg)
Water use	33.15
Water consumption	33.15
Green water	0
Blue water	33.15
Grey water	24.28

- **Plastic**

The Water footprint of plastic is more difficult to determine, the industry and

business of plastic is all over the world, the products of plastic and processes of manufacturing are multifarious. The plastic provide to Tetra Pak converting factory for these 12 types of carton products is LDPE (low density polyethylene).
The source of plastic should be petroleum which is drilled and transport to a refinery and refined to ethane, propane and other hundreds petrochemical of product. And thereby ethane and propane can be transformed into ethylene and propylene which are the raw materials for the LDPE (Simon and Schuster, 1993).
LDPE is quite flexible with high impact strength. It is polymerized from 99.9% pure ethylene raw material, after compressed through two steps, and then it is operated under high temperature and very high pressure, catalyzed in the reactor, afterwards the product of polyethylene is formed by other following steps (Emerson Process Management, 2008) (see Figure 17).

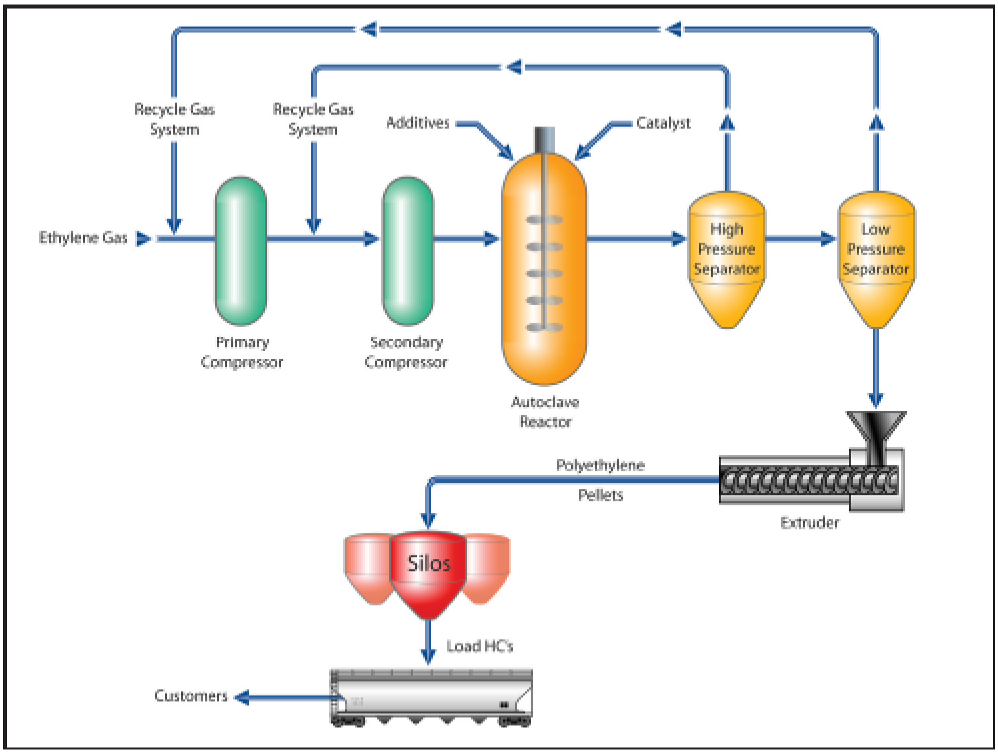

Figure 17 Low Density Polyethylene (LDPE) Processes (Emerson Process Management, 2008).

The direct freshwater used is ranging from 1.2 to 6.5 liters per kilo of finished product (BOREALIS, 2009). The water is excluding a closed cooling system, which transfer the heating energy by changing temperature of water through the reactor walls to a closed-loop jacket cooling system (Charli E. Schuster, 2006), and also excluding the hydraulic power plant which produce energy (electricity) by running or falling water.

According to a research did for a polyolefin industry - Borealis Group, the average Water footprint is 13.7 m^3/t which 20.4% of the total volume, 2.78 m^3/t is used by the electricity power (see Figure 18). And in this research, only Blue water is counted (Stylianos Katsoufis, 2009).

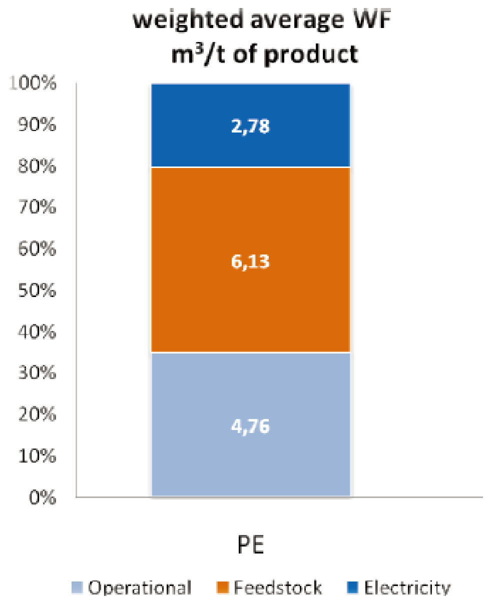

Figure 18 The weighted average cradle-to-gate WF for a ton of PE produced (Stylianos Katsoufis, 2009).

Consider these data all from same source, so the certain volume of water used for cooling system is one part of the total blue water according to Borealis' research, thereby the water use is the total volume which is 13.7 l/kg, and water consumption should excluding the amount of water for the cooling and hydraulic power this two part, then it will be about 6 liters of freshwater per kilo LDPE.
The source of water is Blue water, no Green water is involved, and by following Borealis' research, there are extensive wastewater treatment applied in all facilities, then assume that there is no Grey water produced (Stylianos Katsoufis, 2009). The water footprint of plastic is shown as Table 11.

Table 11 The water footprint of plastic

Water footprint of Plastic	Volume(l/kg)
Water use	13.7
Water consumption	6
Green water	0
Blue water	13.7
Grey water	0

- **Products**

☐ **Milk**

From a research of virtual water is measured that to produce 1 glass of milk need 200 liters of water, and a glass normally equals 250ml so that which means the water need is 800 liters of water to produce per liter milk (WFN, 2008). But this data do not showing the details of water used, it might be already included the water used of processing part in the milk production factory.

At the same time, there are other ways to calculate the water footprint of milk which are more complicated. Whereas most of the details should be considered, it can show more specific information about the water footprint. Following questions and steps are taken:

- **How much milk does a cow produce**?

There are six kinds of daily cows on the world can make milk, and a cow can produce nearly 9000kg of milk which means almost 8800 liters of milk a year (ADA&DC, 2006). Transform the unit to per day which is nearly 25 liters of milk can be produced by a cow.

There are two main parts of water footprint involved with a cow's daily needs, direct water for cow's drinking and the indirect water of the grass which cow eat. Thus the following questions can be figured out:

- **How much water does a cow drink?**

A typical milk producing cow drinks 100 to 200 liters of water per day (ADA&DC, 2006). According the reference of NRC, under the 21℃ of temperature condition, a 500 kg weight cow drinking 35 to 75 liters of water per day (NRC, 2000). A cow must drink 2 liters of fresh, clean water for every liter of milk (MooMilk, 2004).

- **How much grass does a cow eat?**

As a question "how much grass does a cow need in a day?" answered by people on the internet, "Cows will consume between 2.0% and 2.2% of their body weight on a dry basis (like hay) of an average quality feed" on a question and answer plat which named Chacha. And from WikiAnswer website the answer of the same question is 2-2.5%. So if a cow weighs 500 kg, then the dry matter needs is around 12 kg per day. And there is 16% of dry matter and other 84% of water contained in grass (Trish Lewis, 2005). Then the total weight of grass a cow need every day is about 80 kg.

- **How much water does grass need to grow?**

This ca not be figured out properly. The water of grass need depend on Soil situation, weather of plant region, variety of grass, daily luminance, shaded versus sunny area, sprinkler heads and habitual way of watering, etc (Caryn Walz,2009).

For watering an artificial grass lawn, 2.5 to 4 cm water per week is needed (University of Illinois Extension, 2009). And from the WikiAnswer website, an answer information is found out: there are about 1.5×10^3 blades of grass in 1 square meter grass lawn. With that the water need for grass lawn will be 300 to 600 liters of water need per dag for square meter grass lawn and which mean 0.2 to 0.4 liters of water for a blade of grass per day.

A blade of grass weigh 10 gram, so 1 kg grass will be 100 blades. And then the water used for 1 kg grass is 200~400 liters, so that the water footprint of the amount of grass a cow eat everyday is 1600~3200 liters. Here the volume is assumed as 3000 liters per day of grass for a cow eating, and it will be about 120 liters of water for cow eating to produce a liter of milk.

Therefore, the Water footprint of milk is the total volume of direct water cow drink and indirect water of grass. In this case, the grass land is assumed as natural field and the volume of water grass absorbing from soil is considered as the same amount as the water using for a grass lawn, so the source of water for grass is from the rainfall and then bound in the soil, it is green water.
Thereby the water consumption of a cow need to produce milk is selected as 2 liters of water to produce per liter milk. About the source of water which the cows drink is mainly from surface water source, so that it counts as blue water, and the grey water is considered the same volume of water cows taking and then they release out every day. But the water consumption is also the same volume of total water use here.

Table 12 Water footprint of Milk.

Water footprint of Milk	Volume(l/l)
Water use	122
Water consumption	122
Green water	120
Blue water	2
Grey water	2

☐ **Juice:**

Table 13 Water recommendations for fruits (Rodney A. Smith, 1999).

Name	Water demands	Name	Water demands
Banana	Very high	**Blackberry**	High
Blueberry	Very high	**Cherry**	High
Strawberry	Very high	**Citrus**	High
		Currant	High
Gooseberry	High		
Kiwi	High		
Mango	High	**Fig**	Low
Nectarine	High	**Grape**	Low-Medium
Papaya	High	**Apple**	Low-Medium
Peach	High	**Apricot**	Medium
Persimmon	High	**Plum**	Medium
Raspberry	High	**Pear**	Medium-High

The Juice products contain the natural ingredients contained in fruit and vegetables, the products content and the labeling of juices are subject to different regulations. More than 20 kinds of juice products are popular on the world and also getting more and more (Tetra Pak Magazine, 2009). So that the water demands for the fruit trees and vegetables have a very wide range (e.g. see Table 13). Apple juice is selected to be an example to show the general idea of Juice.

There is different between the water footprints of each product. As same as milk, the virtual water used to produce 1 liter of apple juice need about 1000 liters water (Hoekstra, A. Y and Chapagain, A. K, 2007). And also this data is including the water used in processing part which producing juice from fruits, but may excluding the Gross Green water footprint.

So otherwise, there is a raw way to calculate the water footprint of apple juice which is following the processes from tree to juice.

A tree can produce average 400 kg apples (ArcaMax Publishing, 2008) per year. To make 1 liter of juice it need 12-16 apples, which the average weight is 150 g (Corydon Ireland. 2000) to 300 g (WikiAnswer, 2009) for an apple. Hence about 3 kg of apple make 1 1iter of juice, and one apple tree can produce 150 liters of apple juice per year.

As assumed at the beginning of paper data collection part, here an apple tree also assumed need to absorb 700 liters water per day. So to make a liter of juice, need 1500 liters of water.
The source of water used is considered as Green water. And the Grey water can be ignored because of natural fruit plants.

Table 14 The water footprint of Juice.

Water footprint of Juice	Volume(l/l)
Water use	1500
Water consumption	1500
Green water	1500
Blue water	0
Grey water	0

Normally there is 84% embedded water of apple (Anon, 2009), then the water used is obviously decreased to 120 liters to produce one liter apple juice.

5.4. PET bottle

In order to have a good idea on water used during the production of carton packages and to compare it with that of Pet bottles. The weight of 1 liter capacity PET bottle is 40 grams, which the bottle is around 38 grams and the cover is about 2 grams, there is 2 liters of water consumed in the production process (Pacific Institute, 2009). Although here this 2 liters of water is only the direct water consumed in the operational process, not include the indirect water using, it means the only a part of Water consumption which consumed in the operational chain to be measured out here for PET bottle.

6. RESULTS AND DISCUSSIONS

6.1. Calculation

The calculation is done in the excel model and not complicated. It is analyzing the data from the excel database and consisting of simple formulas which can calculate the water footprint in each process.

6.2. Results

The results part is split into two parts: output frame and diagrams. The output frame gives a general idea and clear view of the data. The output data is also shown in diagrams to give a visual representation.

6.2.1. Output frame

PACKAGE NAME	TFA 250	Product :	Milk	Location	Jurong/SIN	Water stress	Yes	
Data / Name				Product	Raw material			
WF	Processing	Filling	Converting	Milk	Paper	Al	Plastic	Total
water use	0.25	0.00352174	0.007069	30.5	32.21044372	0.019705516	0.032077117	63.02281736
water consumption	0.25	0.00352174	0.000105	30.5	32.18025021	0.019705516	0.018731163	62.97231411
Green	0	0	0.000000	30	32.14351476	0	0	62.14351476
Blue	0.25	0.00352174	0.007069	0.5	0.066928962	0.019705516	0.032077117	0.879302596
Grey	0.25	0.00326087	0.000105	0.5	0.035477382	0.014432878	0	0.803276612

Figure 19 Output frame of one example.

The output frame is shown for one product (see Figure 19). It shows the package and product name, location and the water environment, what level of water stress that region is facing. The water use, water consumption and green, blue and grey water are showed for each process. This gives clear information about the water footprint through the entire value chain.

6.2.2. Total Water footprint of all packages

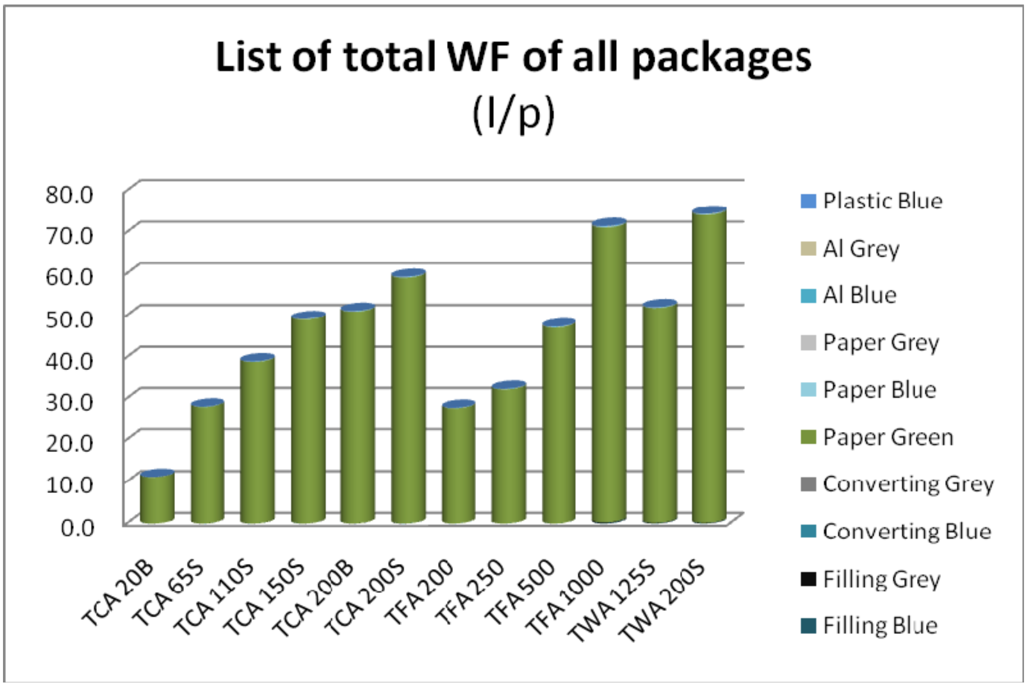

Figure 20 Total Water footprint of all packages.

The gross green water is the main part of the total water footprint of all packages, and the other processes are only a small percentage. The highest water footprint is for the TWA200S which is about 74.4 liters. The lowest is TCA20B, it is the smallest volume which means that it has the smallest package area and least material weights. TFA1000 is the biggest volume in these 12 but it has a smaller water footprint than TWA200S, this is due to different design which means the different thickness of paper layer. From this general overview, the package system with the lowest water footprint is TFA series then is TCA series and finally TWA series is consistent with the raw materials used in the packages.

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6.2.3. Water footprints of TCA200S/TFA200/TWA200S packages

TCA200S, TFA200 and TWA200S, these three packages were selected; they are the same volume, but different design. Only package is considered here.

6.2.3.1. Gross green water footprint and net green water footprint

The gross green water is the total water used for crop's evapotranspiration during its growth period and the "Net Green water footprint" is the difference of amount of water used between the crop evapotranspiration and the natural evapotranspiration (WWF, 2009).

The left figure is showing the gross green water. The total water footprint is mainly gross green water, consumed in the supply chain - the trees.
As the discussion between the gross green water and net green water, an assumed percentage which is 10% of gross green water is taken here as the right figure showed.

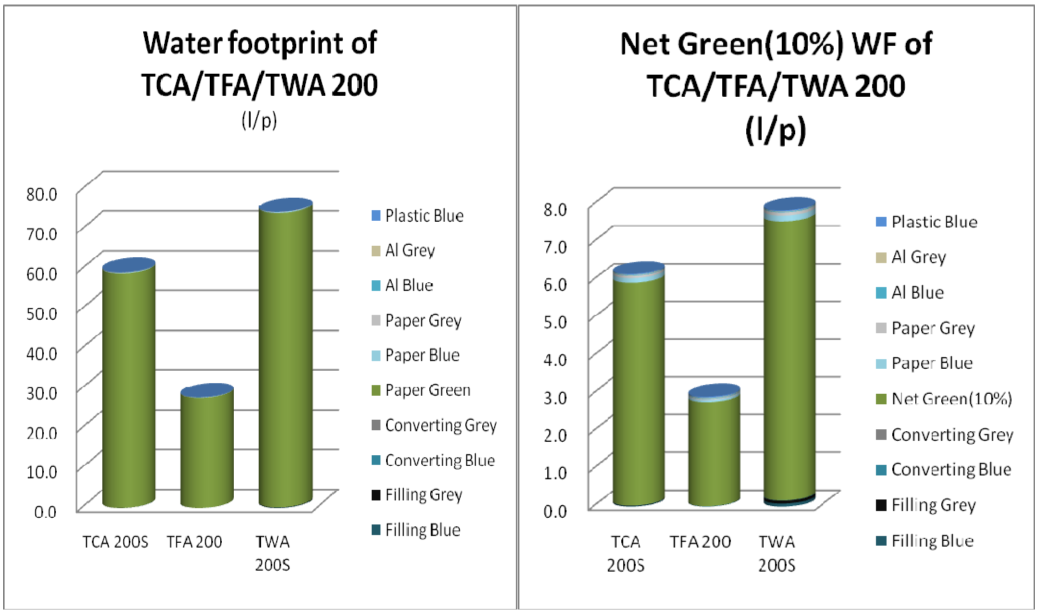

Figure 21 Water footprint of TCA/TFA/TWA 200 packages (Gross green water and Net green water 10%).

The other processes are more visible though still a small part. The total water footprint (assume the net green water is 10% of gross green water) is less than 7.5 liters per package for TWA package.

6.2.3.2. Embedded water

Embedded water is the actual water taken from the original sources, contained in the wood. Then the total water footprint of embedded water is quite low (see Figure 22), which like TWA200S package only take 0.45 liters per package which is really low and for the TFA200 package it is less than 0.15 liters per package.

The water footprint of raw materials part which is the embedded water no long occupies the main volume of the total water footprint. Comparing with gross green water and net green water, it is obviously decreased.

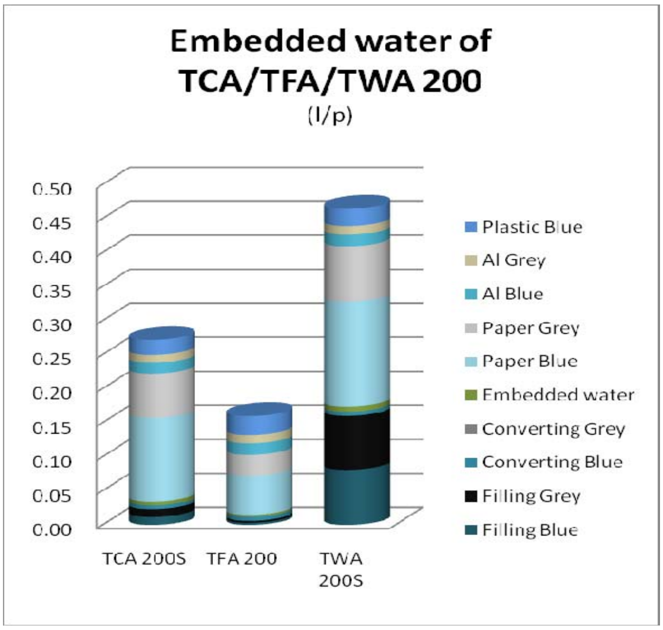

Figure 22 Embedded water footprint of TCA/TFA/TWA 200 packages.

Meanwhile, other processes are identified in the figure. The blue and grey water are clear in each process. Instead of the raw material, more water is used in other parts like aluminum and paper industries, the water footprint of converting factory and the embedded water are the lowest parts. TWA200S use more water footprint than other two packages in filling process, this because of the different filling machine.

6.2.3.3. Three components of embedded water footprint

Comparing three components of the embedded water footprint of these three packages, they all have large supply chain water footprint, the end-use water footprint is smaller, but the operational water footprint which taking place in Tetra Pak converting is very small, not even visible in this figure. Due because the different filling machine used, the package TWA200S has much higher end-use water footprint than other two packages.

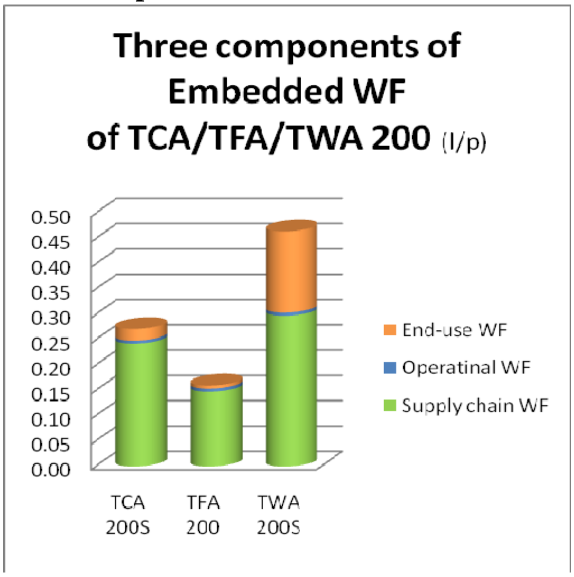

Figure 23 Three components of embedded water footprint of TCA/TFA/TWA 200 packages.

6.2.4. TFA Series (TFA200/TFA 250/TFA 500/TFA 1000)

Four packages of TFA series are selected, there are TFA200, TFA250, TFA500 and TFA1000, Which means the volume of packages are 200, 250, 500 and 1000 ml.

6.2.4.1. Per liter package (gross green & embedded water)

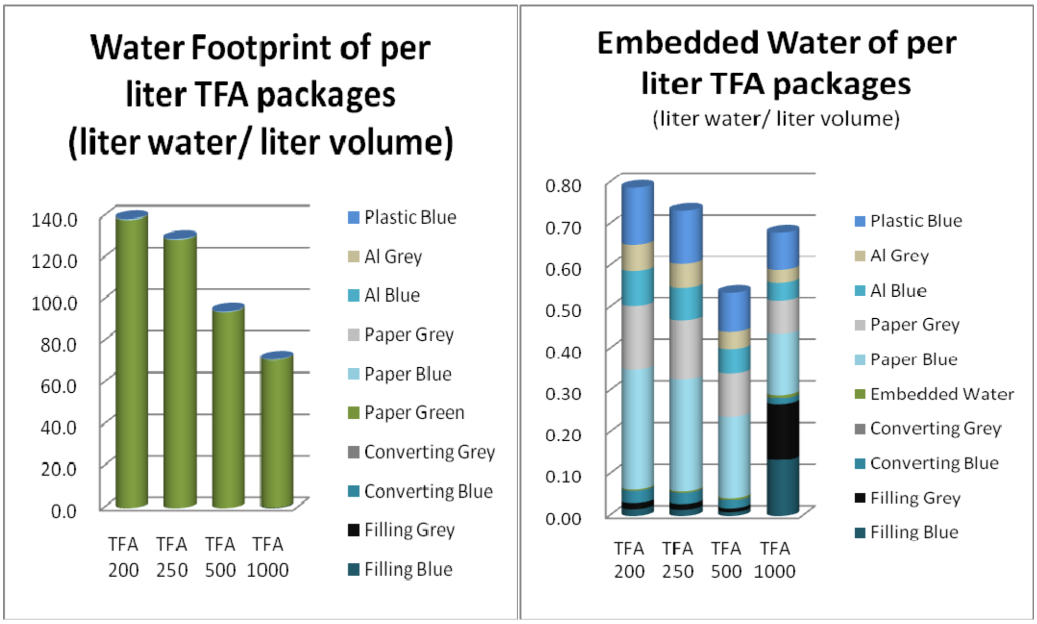

Figure 24 Water footprint of TFA Series per liter package (Gross green & Embedded water).

According to the total water footprint list, the water footprint will be increasing with the volume, TFA1000 is the biggest package. Looking at the water footprint per liter package meaning the water footprint of packages with 1 liter product, like 1 of TFA1000 package, or 5 of TFA200 packages. The TFA1000 package has the lowest water footprint 70 liters per liter package in this case, the TFA200 package has the highest at about 140 liters per liter package. Still, the green water of raw materials is the main part.

From this sensitive point of view, embedded water footprint is less than 0.8 liter per liter package. TFA500 has the lowest water footprint at about 0.52 liter per liter packages. The blue water used in paper industry is the largest part for TFA200, TFA250 and TFA500, but the TFA1000 has larger water footprint in the filling process, this is the reason of TFA1000 has more water used than TFA500 per liter packages.

6.2.4.2. With product (milk & apple juice)

The water footprint including products is much higher than only packages (see figure 25), because of the fact that there was big amount of green water consumed when growing these specific products. For the water footprint of TFA1000 with product milk is about 190 liters per package, replace milk with apple juice it is more than 1500 liters per package. The raw material, the green water of the product takes main part, especially with product apple juice. So that the water footprint of Tetra Pak supply chain became a smaller portion.

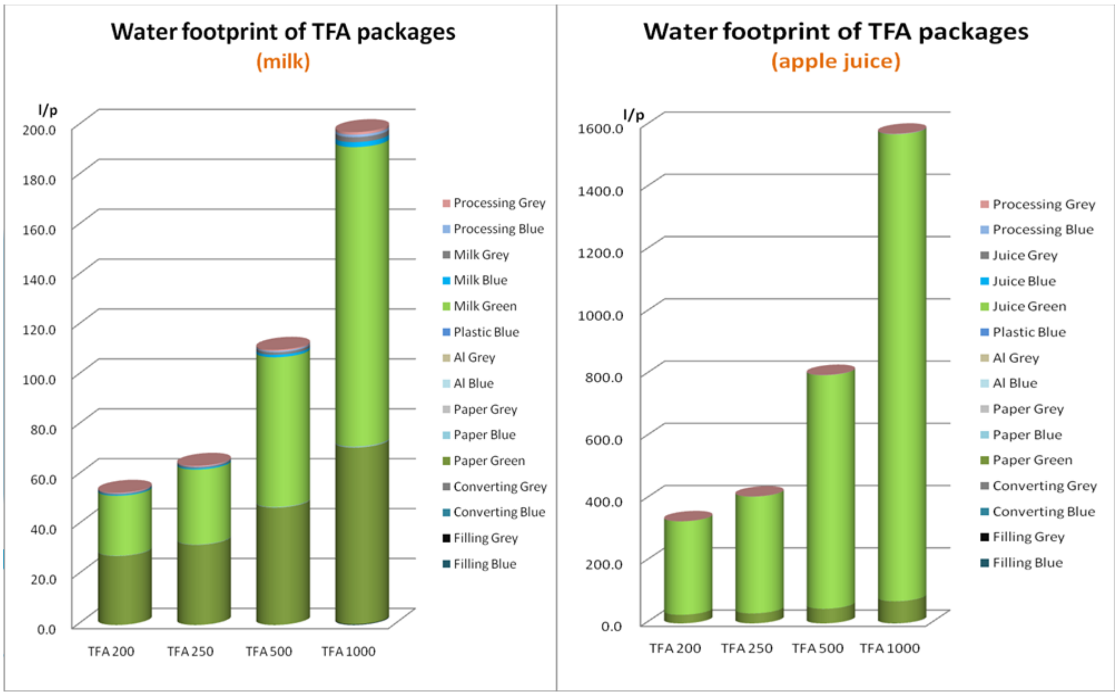

Figure 25 Water footprint of TFA series packages (with products).

6.3. Carton/PET Comparing

Table 15 The WF of Tetra Pak Carton package comparing with water consumed of PET bottle.

	TFA1000	both1 liter volume package		PET
Supply chain WF	Gross Green 71.25 liter	10% Net Green 7.125 liter	Embedded 0.40 liter	HDPE 0.224 liter
Operational WF	0.016 liter	0.016 liter	0.016 liter	2 liter
End-use WF	0.267 liter	0.267 liter	0.267 liter	

To produce a 1-liter PET bottle, 2 liters of waters is used (see Table 15), this is only the operational water footprint. Using a TFA1000 package to compare with the PET package, the operational water footprint of TFA1000 is only 0.016 liter. If the supply chain water footprint is included, the figures change. For TFA1000 package most of the water footprint is consumed there, and for the PET package it is only 0.224 liter (Stylianos Katsoufis, 2009). But if look at the embedded water, the supply chain water footprint of TFA1000 is only 0.4 liter and consider tree is a renewable resource and other factor, carton package has its own advantage.

7. CONCLUSIONS

- **Achievement**

The concept of "water footprint" was developed in the report, the definition of blue water is very clear; also the difference between gross green water, net green water and embedded water was discussed with the specific comparing of different packages. Meanwhile, the definitions of water use and water consumption were developed as assistant to help understand and the main processes involving water. Data was collected for the main processes after setting the boundaries and limitations. A water footprint model of Tetra Pak carton packages was developed and the volume of water footprint in each process was calculated.

- **The water footprint in Tetra Pak**

The way chosen to calculate the green water made a great impact on the total water footprint of the Tetra Pak carton packages. Green water for the raw material, paper, is the major part in the total water footprint. The difference between gross green water footprint and embedded water footprint is observable large.

- **Gaps and limitations**

Since the concept of "water footprint" is still developing, not all parameters necessary were available during the data collection process from the converting factories. For example, like the data collected for grey water from the converting factory in Izmir of Turkey converting factory has the amount of water required to dilute the pollutants, whereas Jurong of Singapore only has the total output.

Also because of the limitation, there is no possibility to go into details about the raw materials. The data needed to calculate the raw materials water footprint with reliability and certainity is simply not there yet. There might also be some other impacts like the water footprint of hydraulic power.

Because lack of the supply chain information, the water footprint as a geological indicator could not be well accessed, this is one of the important concepts of the water footprint to indicate the problems which have strong impacts on the water stress countries when the international business trades between different regions which have different water conditions.

- **Improvements**

To reduce or offset the water footprint, Tetra Pak can create wastewater treatment plant in their converting factories, and apply the recycling systems like in Izmir.

- **The water footprint in the future**

Water is one of important environmental elements, more and more countries are facing water stress and water scarcity, so the water footprint will likely to be a key concept to understand and assess the impacts on environmental issues and businesses.

Coca cola one of the biggest Tetra Pak customers has already pay attention on the water footprint, and Borealis the Swedish plastic company has already done some research on this area.

Tetra Pak as “An environment friendly company” will be look forward at the water footprint.

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APPENDIX

A. Questionnaires for converting factories.

1. Is there any water problem in your region? (*like: Water shortage; water pollution; etc*)
2. Have you heard about water footprint before?
3. Is there any activity to offset and reduce water use in your factory?
4. What do you think it might be the way to reduce water use in your factory?
5. What do you think of water as an environmental factor?
6. The capacity of carton products in your factory
   2007:____(MSP/year); 2008:____(MSP/year); 2009:____(MSP/year)
7. The total water used in your factory
   2007:____(m^3/year); 2008:____(m^3/year); 2009:____(m^3/year)
8. The amount of water used in the production of carton products:
   2007:____(m^3/year); 2008:____(m^3/year); 2009:____(m^3/year)
9. What source is the water from, and how much of each?
   ① Rain water (like collecting from roof) ______ (m^3/year)
   ② Fresh water from water supply company_____ (m^3/year)
   ③ Water from river/ lake/ groundwater ______ (m^3/year)
   ④ Other source 1______ (m^3/year)
   Other source 2______ (m^3/year)
10. Which process is the water used for in your factory, and how much of each?
    ① Washing ______ (m^3/year)
    ② Cooling _____ (m^3/year)
    ③ Diluting the pollutant of wastewater to meet standards _____ (m^3/year)
    ④ The volume of wastewater transport to wastewater treatment plant _____ (m^3/year)
    ⑤ Is any kind of wastewater release to the river or sea _______(m^3/year)and the quality?
    ⑥ Is there any water used for heating _______(m^3/year)?
    ⑦ Others 1_____________ (name of the process) ______ (m^3/year)
    Others 2_____________ (name of the process) ______ (m^3/year)
11. Do you have any water recycle system? What is it? And the volume of recycled water per year?
    No, there's no recycle system in our factory.
    Yes: we have water recycle system for __________ (name; *like cooling*) ______ (m^3/year)

B. Table 16 List of water ratio of trees (Nebraska Extension office, 2002).

Species	green weight	dry weight	ratio d/g	percent water
Apple	4850	3888	0.8016	19.84%
Ash	4184	2880	0.6883	31.17%
Basswood	4404	1984	0.4505	54.95%
Birch	4312	2992	0.6939	30.61%
Boxelder	3589	2632	0.7334	26.66%
Buckeye	4210	1984	0.4713	52.87%
Catalpa	4560	2360	0.5175	48.25%
Cherry, black	3696	2928	0.7922	20.78%
Coffeetree	3872	3112	0.8037	19.63%
Cottonwood	4640	2272	0.4897	51.03%
Douglas-fir	3319	2970	0.8948	10.52%
Elm American	4456	2872	0.6445	35.55%
Elm Red	4800	3112	0.6483	35.17%
Elm Siberian	3800	3020	0.7947	20.53%
Fir, Concolor	3585	2104	0.5869	41.31%
Hackberry	3984	3048	0.7651	23.49%
Hickory,Bitternut	5032	3832	0.7615	23.85%
Hickory, Shagbark	5104	3952	0.7743	22.57%
Honeylocust	4640	3832	0.8259	17.41%
Ironwood	4590	4016	0.8749	12.51%
Juniper,Rocky Mt.	3535	3150	0.8911	10.89%
Locust, Black	4616	4016	0.8700	13.00%
Maple, Other	4685	3680	0.7855	21.45%
Maple, Silver	3940	2752	0.6985	30.15%
Mulbery	4712	3712	0.7878	21.22%
Oak, Bur	4960	3768	0.7597	24.03%
Oak, Red	4888	3528	0.7218	27.82%
Oak, White	5573	4200	0.7536	24.64%
Osage-Orange	5120	4728	0.9234	7.66%

Pine, Eastern White	2780	2250	0.8094	19.06%
Pine, Jack	3200	2488	0.7775	22.25%
Pine,Ponderosa	3600	2336	0.6489	35.11%
Redcedar, Eastern	2959	2632	0.8895	11.05%
Spruce	2800	2240	0.8000	20.00%
Walnut, Black	4584	3192	0.6963	30.37%
Willow	4320	2540	0.5880	41.20%
Average	4129	3083	0.7337	26.63%